SCIENTIFIC AMERICAN SUPPLEMENT. No 1588

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Scientific American, established 1845.
Scientific American Supplement, Vol. LXI., No. 1588.

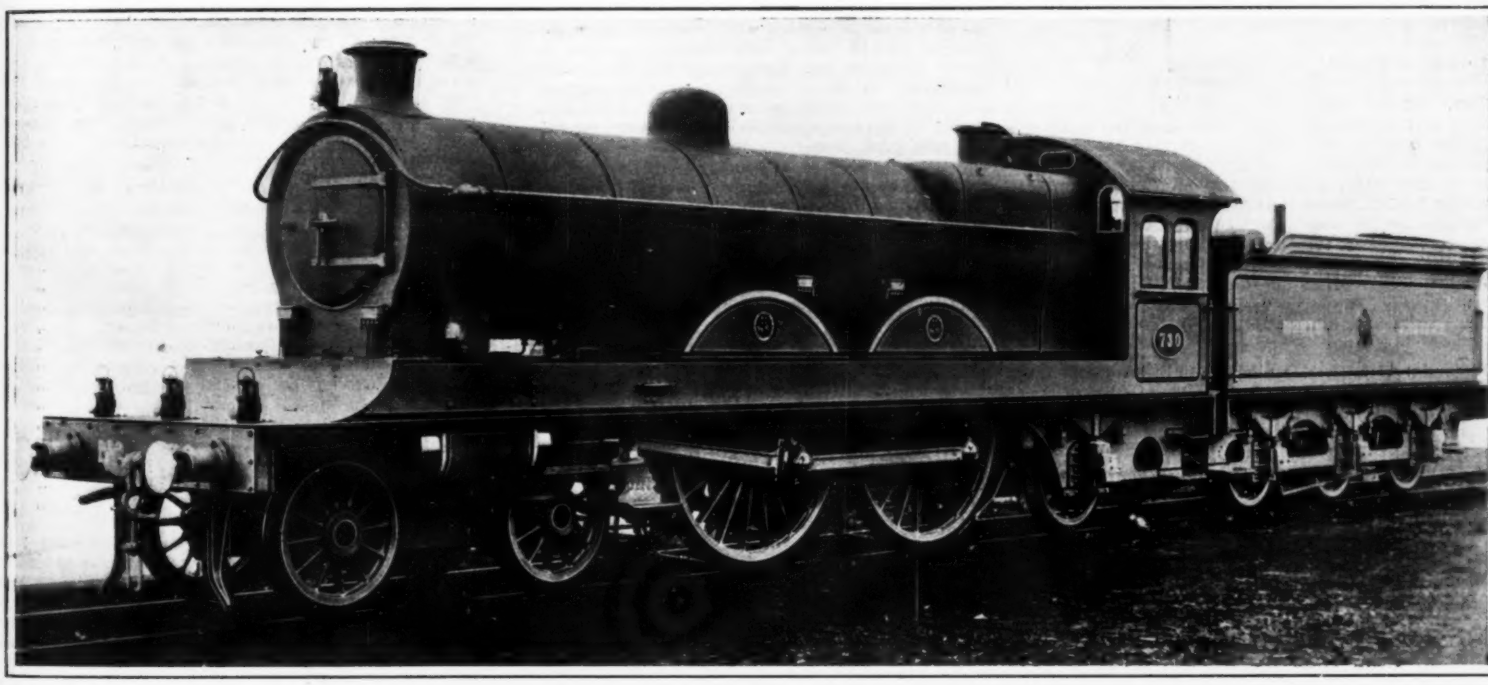
NEW YORK, JUNE 9, 1906.

Scientific American Supplement. $5 a year.
Scientific American and Supplement. $7 a year.

A BRITISH FOUR-CYLINDER BALANCED COMPOUND "ATLANTIC" LOCOMOTIVE.

By H. COLEMAN.

SOME two years ago, Mr. Wilson Worsdell, the chief mechanical engineer of the North-Eastern Railway of England, introduced between York and Edinburgh the first of his design of "Atlantic" simple engines. These locomotives, built to what is practically the maximum proportions for the British railway loading gage, have the following leading dimensions: Cylinders, 20 inches diameter by 28 inches stroke; wheel diameters, bogies 3 feet 7¼ inches; driving, 6 feet 10 inches; and trailing wheels, 4 feet. The coupled wheel-base is 7 feet 7 inches, and the total wheelbase 28 feet. The boiler pressure amounts to 200 pounds per square inch, and the total heating surface to 2,455.8 square feet. The grate area is 27 square feet; the adhesion weight is 39 tons, and the total weight of the engine 72 tons. The tender has accommodation for 5 tons of fuel and 4,125 gallons of water. In working order, the locomotives have an aggregate weight of no less than 115½ tons. While these "Atlantics" are claimed to have performed very efficient service in the hauling of the heaviest and fastest-timed trains over the North-Eastern line, Mr. Worsdell, with a view to settling, as far as is possible, the somewhat vexed question—with British railway engineers—as to the relative efficiency of the simple and the compound types of locomotives, some few months ago put under construction at the Gateshead works of the North-Eastern Railway a new class of four-cylinder balanced compound locomotives of the 4-4-2 wheel arrangement. The first of these locomotives has quite recently been completed, and is depicted in the accompanying photograph and diagram drawing, for the use of which the writer is indebted to the courtesy of Mr. Worsdell. The appearance of these engines marks a new departure in the locomotive practice of the North-Eastern Railway, and, moreover, adds one more cylinder and wheel arrangement to those already used for compound locomotives in Great Britain. The cylinders are arranged in line at the center of the bogie. One set of valve gears actuates the distributing valves for one high and one low pressure cylinder. The first of these locomotives has quite recently been completed, and although only working a non-important train for a few trips, was so successful that it was deemed fit for the main line service, and in this working it has already demonstrated its ability to handle heavy trainloads at express schedules. The engine is stated to be exceptionally quick at starting and soon "accelerates," maintaining high rates of speed while ascending inclines. The engines, Nos. 730 and 731, have been compounded on Mr. W. M. Smith's principle, which was some time ago successfully applied to the three-cylinder four-wheel coupled bogie express passenger locomotives of the Midland Railway, and they are both fitted with the Belpaire pattern of firebox, which is somewhat of an innovation in the locomotive practice of the North-Eastern Railway. Engine No. 730 is fitted with a modification of the Stephenson link motion, while engine 731 has a modified form of the Walschaert valve gear, not hitherto adopted on the North-Eastern Railway. As these two four-cylinder balanced compound "Atlantic" locomotives of the North-Eastern Railway Company are now undergoing a series of exhaustive trials, it is not at the moment possible to give a detailed description of their design and dimensions, beyond stating that the high-pressure cylinders are 14¼ inches in diameter and 26 inches stroke, and the low-pressure cylinders 22 inches in diameter and 26 inches stroke. The total heating surface is 1,962 square feet, to which the tubes contribute 1,782 square feet, and the firebox the remaining 180 square feet. The grate area is 29 square feet, and the boiler pressure 225 pounds per square inch. The diameter of the driving wheels is 7 feet 1¼ inch, of the carrying wheels 4 feet, and of the bogie wheels 3 feet 7¼ inches. The rigid wheelbase is 7 feet 6 inches, and the total wheelbase 52 feet 9¾ inches. In working order, the engine—the first of its type to be built in Great Britain—weighs 73 tons, while the tender, running upon six 3 foot 9¼ inch wheels, weighs an additional 42 tons, so that the locomotives have an aggregate weight on rails of 115 tons.



High-pressure cylinders, 14¼ x 26 inches ; low-pressure cylinders, 22 x 26 inches. Total heating surface, 1,962 square feet. Grate area, 29 square feet. Boiler pressure, 225 pounds per square inch. Weight, 73 tons.

A BRITISH FOUR-CYLINDER BALANCED COMPOUND "ATLANTIC" LOCOMOTIVE.

DIAMETRAL AND CIRCULAR PITCH.

IT is only in recent years that these two pitches have come into serious collision, or been a source of trouble to machinists. The reason is found in the growing appreciation of the diametral, and the lessening use of the circular pitch. At one time the first-named was practically confined to the change wheels of lathes, the light gears of machine tools, and the small wheels of spinning machinery. At that period, it was as often as not termed the "Manchester pitch," a designation now nearly dropped. At the present time this system is adopted on many heavy gears as well as on light ones.

The great convenience of this pitch alone would not have brought about these changed relations, but for the rapid growth of wheel-cutting machinery. Before these changes came it would have been correct to say, as a general statement, that nearly all cut gears were of diametral and all cast gears of circular pitch. That is no longer true, for the systems have overlapped.

Diametral, or, as it is often termed, diametrical, pitch, is a simple expression to denote the number of teeth in a wheel to one inch of the diameter of the pitch circle. It is, therefore, always an even number, which takes no account whatever of fractional measurements in the actual pitch, measured, say, in decimals, or sixty-fourths of an inch, or full, or bare. Diametral pitch, therefore, is a ratio. It denotes the number of teeth in a gear, divided by the diameter. Its basis is the number of teeth in each inch of the diameter. It may also be stated as the number of teeth in a gear of one inch in diameter. Or it may be defined as the length which bears the same relation to the circular pitch as the diameter of a circle bears to its circumference. Another way in which it may be stated is this: Cut off as many pieces of wire as a wheel has teeth, and of such a length, all being equal, that when laid end to end they will extend across the diameter of the pitch (Fig. 1). In this cut *A* is the circular pitch, and the divisions on the diameter, *P D*, are the divisions of diametral pitch. One of these divisions thus becomes a unit, upon which all proportions of the teeth can be based. For convenience only it is stated in terms of the inch.

Circular pitch, on the other hand, Fig. 2, *A*, is an exact arc dimension, measured round the pitch line, as ½ in., 1½ in., and so forth, neither less nor more in any fractional degree.

In the diametral system, therefore, the *pitch diameter* of a wheel is the cardinal and primary measurement, to which the circular pitch must conform, whether it involves fractional measurements round the arc or not. In the circular system the *pitch* is the primary dimension, which fixes the diameter, no matter whether the latter comes out in integers only, or in minute fractional parts.

From the point of view of convenience, a fixed diameter is more convenient than a fixed pitch. Centers of wheels in integers are much preferable to centers in fractional dimensions. On the other side, an exact pitch is of no particular value. A pitch approximate answers all requirements, provided all wheels in a series measure alike in that respect. It is therefore not very easy to understand how the circular system attained such paramount importance, when a more convenient way lay ready to hand. But a nice legacy of confusion has been bequeathed to the machine hand of the present day in consequence of the growth of the two systems side by side. Confusion enough arises in shops, due to the loose way in which orders are given by customers, without being bothered by rival pitches as well. A diameter is often given without stating whether the pitch diameter or the outside is meant. Pitch is given without stating whether diametral or cir-

cular. It must be remembered that "2 pitch" and "2 inch pitch" are very different dimensions, and care should be taken in omitting or inserting the word "inch" when giving an order.

The methods of calculating under each system are as follows:

In the diametral system, the number of teeth in a wheel to 1 inch of the diameter of the pitch circle is the diametral pitch. The diameter of the pitch circle, therefore, multiplied in inches by the diametral pitch equals the number of teeth in the wheel. If a wheel has 20 teeth, and its pitch diameter is 4 inches, there are five teeth for each inch of diameter, and the wheel is of 5 diametral pitch.

$$\frac{20}{4} = 5, \text{ equals the diametral pitch.}$$

Since the basis of the system is the constant relation of diameter to circumference, which equals unity divided by 3.14159.

$$\frac{1}{3.14159} = 0.3183.$$

0.3183 therefore represents the diameter of a circle, whose circumference is 1; so that if a circular pitch is represented by 1, the corresponding diametral pitch is 0.3183; and if a diametral pitch is 1, the circular is 3.14159.

In the diametral system of cutting gears, the diametral pitch is often termed the "module," or "modul," both in America and on the Continent, because it is the basis of all calculations.

To prevent error, it should be stated that there are two ways of stating diametral pitch. It may be given in terms of the inch, or be denoted by a number only. The diametral pitch being the length which bears the same proportion to the circular pitch that the diameter of a wheel bears to its circumference, it may therefore be called, say, ¼ inch or ½ inch, etc. But the usual way to put it is as the reciprocal of this, or the denominator of the fraction divided into one. Thus, for a ¼-inch pitch—meaning by that a quarter of the diametral inch—the reciprocal would be $\frac{1}{1/4} = 4$ pitch, a ½-inch pitch would be $\frac{1}{1/2} = 2$ pitch.

The difference must be borne in mind. In the first-named system, the diametral pitch and the circular inch are both in terms of the inch. In the second, while the circular pitch is in these terms, the diametral is a number only; a 2 diametral pitch, for example, meaning 2 pitch, which it is necessary to convert mentally into the fraction ½ inch to understand.

In circular pitch, the pitch multiplied by the number of teeth gives the pitch circumference, whence the diameter is deduced. Thus—

$$\frac{\text{Pitch in inches} \times \text{number of teeth}}{3.14159} = \text{pitch diameter in inches.}$$

Example: 40 teeth × 1 pitch = 40 inches circumference, and—

$$\frac{40}{3.14159} = 12\tfrac{3}{4} \text{ nearly.}$$

By transposition of the factors, other figures are deduced thus

$$\frac{\text{Pitch diameter} \times 3.14159}{\text{Pitch in inches}} = \text{number of teeth}$$

and—

$$\frac{\text{Pitch diameter} \times 3.14159}{\text{Number of teeth}} = \text{the pitch in inches.}$$

The annoying feature in these relations is that an exact diameter is not usually arrived at, expressed in even eighths, sixteenths, or even thirty-seconds. It generally comes out in some places of decimals; hence the terms "full" and "bare" so often found in figures of pitch diameters of pattern-wheels for foundry use.

A bad point again in the system is the temptation to fudge diameters to suit wheel centers, and to accommodate the pitches thereto by making them full or bare.

Another evil lies in the translation of one class of pitch into the other. We have in the one system pitches which are expressed in exact dimensions, in the other pitches which seldom work out thus. And again we have the fact that no diametral pitch ever corresponds with its equivalent circular pitch, in any exact aliquot fractional parts of the inch, but always to several places of decimals. The formula just now given—namely,

$$\frac{1}{3.14159} = 0.3183,$$

indicates how circular and diametral pitches can be converted into each other. Multiplying the circumference of a circle by 0.3183 gives the diameter of the circle. Hence if a circular pitch which is a part of the circle is multiplied by 0.3183, the result bears the same proportion to the diameter that the circular pitch does to the circumference; in other words, it converts the circular into the diametral pitch, and there are as many diametral pitches in the diameter of the pitch circle as there are teeth in the wheel.

Conversely, if 3.14159 is divided by a diametral pitch, it gives the circular pitch. Putting these as formula we have circular pitch × 0.3183 = diametral pitch, and

$$\frac{3.14159}{\text{diametral pitch}} = \text{circular pitch.}$$

Thus, take 1 inch circular pitch = 1 inch × 0.3183 = 0.3183, which does not correspond with any exact diametral pitch, and so on through any circular pitches. On the other hand, take a diametral pitch, say 6, then—

$$\frac{3.14159}{6} = 0.524 \text{ circular pitch,}$$

which again is not an even number.

The hopelessness of trying to run the two systems as interchangeable systems is thus apparent. This is learned in the shops, where cut gears are wanted sometimes for circular, sometimes for diametral pitches. It is well to keep full-sized sections of teeth based on the diametral system for ready reference; but a close approximation to the circular pitches which correspond with diametral can always be made mentally by remembering that the relation between the two is always that of diameter to circumference, or as one is to 3 1-7, or as 7 is to 22. So that a 4p. (four representing a fourth of an inch) would give ¼ inch × 3 inches = ¾ inch + 1/7 of ¼ inch = ¾ inch full for the corresponding circular pitch; 2p. would give ½ inch × 3 inches = 1½ inch + 1/7 of ½ inch, or a trifle over 1 9/16 inches for the circular pitch. And to derive

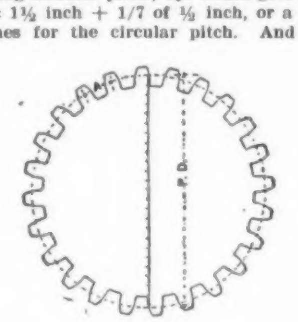


FIG. 1.

diametral pitch from circular the operation would be just reversed.

Either system if taken alone is simple of application; the difficulties arise when any attempt is made to convert one into the other. Yet this is a problem which is now becoming very frequent in consequence of the increasing use of cut gears. It is very puzzling to men who have grown accustomed to the old style of pitch to grasp the principles of the newer system.

A case came under the writer's notice recently in which a machine-shop foreman where a gear-cutting machine was newly introduced came in trouble to the office, saying that a 2-pitch cutter supplied must be wrong, for it did not measure more than 1 9/16 inch pitch. On being assured that it was correct, he went away greatly puzzled at the new-fangled method. Another puzzle to him was the fact that the numbers of diametral pitches rise higher as the pitches became finer.

But diametral pitch is only puzzling when the relation of diameter to circumference is not grasped. The mistake has been made of considering the pitch as equivalent to a division of the circumference, that is 4-pitch as ¾ inch circular pitch, and such like. But the point to bear in mind is that it is a *relation* to the circumference expressed in terms of the diameter. Four-pitch measures rather over ¾ inch, or exactly 0.785 of an inch, that is ¼ inch × 3.14159 inches, and, of course, a 4-pitch is always the same, no matter how many teeth there are in different wheels. It is as hard and fast a dimension as a circular pitch is. The basis is the diametral inch, divided into as many equal parts as the system embodies, usually from two divisions to twenty divisions, and the actual circular pitch is obtained by multiplying these by 3.14159.

In attempting to work on an exact system, men are confronted with these several facts: The diametral and circular pitches cannot be cut correctly with one set of cutters made for either system alone. Yet different customers want sometimes one, sometimes the other. Again, different sets of cutters are wanted for involute and for cycloidal teeth. Cutters with different sized arbor-holes are required for different machines.

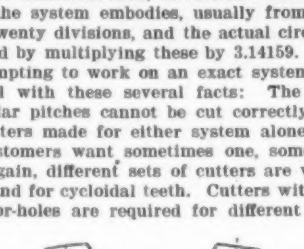


FIG. 2.

For the best results, a larger stock of cutters is required than for average results; and sometimes gears are wanted to conform to the metric system, for which, again, different sets of cutters are necessary. Lastly, in order to derive the fullest advantages from gear-cutting, more than one class and size of machine is required. This is a pretty big list, and a deterrent one in many shops; hence the reason why so much of this work is put out by the trade. And when compromises are attempted the trouble begins.

Confining our attention only to the two points raised in the early part of this article, the commonest problem is probably that of using the standard cutters for diametral pitch, to cut wheels of circular pitch by. Of course, the proper way is to order sets of cutters for each class of wheel. But we are now talking of make-shift devices. It is done by selecting a cutter which comes nearest to the circular pitch required. Thus a 4-pitch is the closest to a ¾-inch circular pitch, with a variation of about 1/32 inch—a serious difference. A 3-pitch is very close to a 1-inch circular pitch. A 2½-pitch is very near to a 1¼-inch circular pitch. The blank is then sized for circular pitch, and the diametral cutter used. This, of course, is not recommended for adoption in regular practice, but it is justifiable at a pinch, and in the worst cases it is preferable to a badly-cast gear. The deviation from strict accuracy, however, is not quite so serious as appears from the difference in the pitch of the cutters. The tooth thickness and spaces come out above or below exact dimensions; but the involute is so elastic a type that the meshing of the teeth is practically unaffected. On large wheels, say, of over fifty teeth, the difference is much less apparent than it is on smaller wheels, say below twenty teeth, in which the deviations from accuracy are more obvious. But it is practicable to make decent gears in most wheels by using diametral cutters, and this has been done on several occasions within the writer's knowledge, with satisfactory results.

Some such compromise as this is inevitable as long as the two systems of pitches exist in rivalry. Many firms are committed to one, many to the other. The circular, as the older, is still the more generally employed. But the diametral is pushing it hard in modern shops, as the demand for cut gears grows. The displacement of the first-named system by the second is perhaps now most obvious in machine tools, but it has invaded other departments, notably cranes, in which large quantities of gears are required, and which are now very commonly specified to be cut.

Another result is that the involute gears are displacing the cycloidal. The reasons are, first, that the involute have been mostly employed all along in connection with the diametral system, and second, that the sets of cutters cost less for the involute than the other system, being fewer in number.

In the involute system eight cutters form a standard set, which will, between them, cut all wheels from twelve teeth to a rack. This, of course, is a compromise, because some of the shapes of the cutters are a medium. It is well known by those whose work has lain in gearing, that the differences between the forms of teeth are very much greater in small pinions, differing by two or three teeth, than in large wheels having a similar difference. So that while a No. 2 cutter will serve for all wheels from 55 to 134 teeth, a No. 7 will only cut from 14 to 16. And further, though these eight cutters constitute a standard set, they are not sufficiently exact for the requirements of all the best gear-cutting done. For these, intermediate cutters are supplied, numbered by halves, so that a complete set includes the following:

No.	1	will cut	wheels	from	135 teeth	to	a rack
"	1½	"	"	"	80	"	134 teeth
"	2	"	"	"	55	"	134 "
"	2½	"	"	"	42	"	54 "
"	3	"	"	"	35	"	54 "
"	3½	"	"	"	30	"	34 "
"	4	"	"	"	26	"	34 "
"	4½	"	"	"	23	"	25 "
"	5	"	"	"	21	"	25 "
"	5½	"	"	"	19	"	20 "
"	6	"	"	"	17	"	20 "
"	6½	"	"	"	15	"	16 "
"	7	"	"	"	14	"	16 "
"	7½	"	"	"	13	"	.. "
"	8	"	"	"	12	"	13 "

The cycloidal cutters are not essentially related to the system of circular pitch, but they have generally been so associated. They have been employed also much more generally than the involute. Sets of cycloidal cutters are made for both systems. But while the standard set of involutes is eight, that for cycloids is twenty-four, a striking illustration of the great elasticity of the single-curve tooth system over that of the double curve. In the latter set separate cutters are wanted for each single pinion from 12 to 20 teeth, advancing by a single tooth only. That is for cutting pinions from 12 teeth to 20 inclusive, nine cutters are required, or one more than the complete standard set for involutes. And then they advance by twos or by threes, and gradually increasing increments until the last one, which cuts a rack.

Another point is that the cutters for cycloidal teeth have shoulders to prevent risk of their cutting too deeply into the blank. The maintenance of the exact position of the pitch circle is most essential to correct gear. It is the line from which the double curves start, and if these lines do not coincide, the curves do not engage perfectly. The system is, therefore, more costly and less elastic than the involute.—English Mechanic and World of Science.

[Continued from SUPPLEMENT No. 1587, page 25428.]

CEMENT MATERIALS AND INDUSTRY OF THE UNITED STATES.*

By EDWIN C. ECKEL.

Wet Methods of Grinding and Mixing.

WET methods of preparing Portland-cement mixtures date back to the time when millstones and similar crude grinding contrivances were in use. With such imperfect machinery it was almost impossible to grind dry materials fine enough to give a good Portland-cement material. In this country the advent of good grinding machinery has practically driven out wet methods of manufacture, except in dealing with materials such as marls, which naturally carry a large percentage of water. Two plants in the United States add water to a limestone-clay mixture, but the effect

* Abstract from Bulletin 243 of United States Geological Survey.

of this practice on the cost sheets of these remarkable plants can hardly be encouraging.

The location, physical condition, and chemical composition of the marls and clays used have important effects upon the cost of the wet process. Marl deposits of workable size occur only in the Northern States and in Canada, and consequently the climate is unfavorable to continuous working throughout the year, for the marl is usually covered with water, and in winter is procured with difficulty. Marl deposits are necessarily and invariably found in depressions, and the mill must be located at a higher level, which involves increased expense in transporting the raw material to the mill.

Glacial clays, which are usually employed in connection with marl, commonly carry a much larger proportion of sand and pebbles than the sedimentary clays found farther south.

The effect of the water carried by the marl has been noted. The material as excavated consists approximately of equal weights of lime carbonate and of water, and more water is often added to permit the marl to be pumped up to the mill.

At the mill the clay is often dried in order to simplify the calculation of the mixture. The reduction of the clay is commonly accomplished in a disintegrator or in edge-runner mills, after which the material is further reduced in a pug mill, sufficient water being here added to enable it to be pumped readily. It is then ready for mixture with the marl, which has been screened to remove stones, wood, etc. The slurry is further ground in pug mills or wet grinding mills of the disk type, while the final reduction commonly takes place in wet tube mills. The slurry, now containing 30 to 40 per cent of solid matter and 70 to 60 per cent of water, is pumped into storage tanks, where it is kept in constant agitation to avoid settling. The slurry is analyzed at this point, and the mixture in the tanks is corrected if found to be of unsatisfactory composition. After standardizing, the slurry is pumped into the rotary kilns. Owing to the large percentage of water in the slurry, the fuel consumption per barrel of finished cement is 30 to 50 per cent greater, and the output of each kiln correspondingly less than in the case of a dry mixture.

It may be of interest, for comparison with the above description of the wet process with rotary kilns, to insert a description of the semi-wet process, as carried on a few years ago at the dome-kiln plant of the Empire Portland Cement Company, of Warners, N. Y. The plant has been remodeled since that date, but the processes formerly followed are still of interest, as they resulted in a high-grade though expensive product.

At the Empire plant the marl and clay were obtained from a swamp about three-fourths of a mile from the mill. A revolving derrick with clam-shell bucket was employed for excavating the marl, while the clay was dug with shovels. The materials were taken to the works over a private narrow-gage road, on cars carrying about 3 tons each, drawn by a small locomotive. At the mill the cars were hauled up an inclined track, by means of a cable and drum, to the mixing floor.

The clay was dried in three Cummer "Salamander" driers, after which it was allowed to cool, and then carried to the mills. These mills were of the Sturtevant "rock emery" type, and reduced the clay to a fine powder, in which condition it was fed, after being weighed, to the mixer. The marl was weighed and sent directly to the mixer, no preliminary treatment being necessary. The average charge was about 25 per cent clay and about 75 per cent marl.

The mixing was carried on in a mixing pan 12 feet in diameter, in which two large rolls, each about 5 feet in diameter and 16-inch face, ground and mixed the materials thoroughly. The mixture was then sampled and analyzed, after which it was carried by a belt conveyor to two pug mills, where the mixing was completed and the slurry formed into slabs about 3 feet long and 4 to 5 inches in width and height. These on issuing from the pug mill were cut into a number of sections, so as to give bricks about 6 by 4 by 4 inches in size. The bricks were then placed on slats, which were loaded on rack cars and run into the drying tunnels. The tunnels were heated by waste gases from the kilns, and from twenty-four to thirty-six hours were required to dry the bricks.

The bricks after drying were fed into dome kilns, of which there were 20, and which were charged with alternate layers of coke and slurry bricks. The coke charge for a kiln was about 4 or 5 tons. This produced 20 to 26 tons of clinker at each burning, thus giving a fuel consumption of about 20 per cent, as compared with the 40 per cent or more required in the rotary kilns using wet materials. From thirty-six to forty hours were required for burning the charge. After cooling the clinker was shoveled out, picked over by hand, and reduced in a Blake crusher, Smidth ball mills, and Davidsen tube mills.

The cement mixture ready for burning will commonly contain from 74 to 77.5 per cent of lime carbonate, or an equivalent proportion of lime oxide. Several analyses of actual cement mixtures are given in the table below. Analysis No. 1, with its relatively high percentage of magnesia, is fairly typical of Lehigh Valley practice. Analyses Nos. 2 and 3 show mixtures low in lime, while analysis No. 4 is probably the best proportioned of the four, especially in regard to the ratio between silica and alumina plus iron. This ratio, for ordinary purposes, should be about 2.5 or 3 to 1, as the cement sets quicker and has less ultimate strength as the percentage of alumina increases. If the alumina percentage be carried too high, moreover, the mixture will give a fusible, sticky clinker when burned, causing trouble in the kilns.

Analyses of Cement Mixtures.

	1	2	3	4
Silica (SiO_2)	12.62	13.46	13.85	14.77
Alumina (Al_2O_3) and iron oxide (FeO)	6. 0	(?)	7.20	4.35
Lime carbonate ($CaCO_3$)	75.46	73.66	73.93	76.84
Magnesia oxide (MgO)	2.65	(?)	(?	1.74

Burning the Mixture.

After the cement mixture has been carefully prepared, as described in preceding pages, it must be burned with equal care. In the early days of the Portland-cement industry a simple vertical kiln, much like that used for burning lime and natural cement, was used for burning the Portland-cement mixture. These kilns, while fairly efficient so far as fuel consumption was concerned, were expensive in labor, and their daily output was small. In France and Germany they were soon supplanted by improved types, but still stationary and vertical, which gave very much lower fuel consumption. In America, however, where labor is expensive, and fuel is comparatively cheap, an entirely different style of kiln has been evolved. This is the rotary kiln. With the exception of a very few of the older plants, which have retained vertical kilns, all American Portland-cement plants are now equipped with rotary kilns.

Summary of Burning Process.

The rotary kiln is a steel cylinder about 6 feet in diameter and, for dry materials, 60 or 80 feet long. For wet mixtures a kiln 80 to 100 feet long, or even longer, is frequently employed. This cylinder is set in a slightly inclined position, the inclination being approximately one-half inch to the foot. The kiln is lined, except near the upper end, with very resistant fire brick, to withstand both the high temperature to which its inner surface is subjected and the destructive action of the molten clinker.

The cement mixture is fed in at the upper end of the kiln, while fuel (which may be either powdered coal, oil, or gas) is injected at its lower end. The kiln, which rests upon geared bearings, is slowly revolved. This revolution, in connection with the inclination at which the cylinder is set, gradually carries the cement mixture to the lower end of the kiln. The intense heat generated by the burning fuel first drives off the water and carbon dioxide from the mixture and then causes the lime, silica, alumina, and iron to combine chemically to form the partially fused mass known as "cement clinker." This clinker drops out of the lower end of the kiln, is cooled so as to prevent injury to the grinding machinery, and is then sent to the grinding mills.

Theoretical Fuel Requirements.

As a preliminary to a discussion of actual practice in the matter of fuel, it will be of interest to determine the heat units and fuel theoretically required in the manufacture of Portland cement from a dry mixture of normal composition.

In burning such a mixture to a clinker the heat needed will be the amount required for the dissociation of the lime carbonate into lime oxide and carbon dioxide. A small additional amount of heat will be required to drive off the water that is chemically held by the clay or shale and to decompose any calcium sulphate (gypsum) that may be present. The amount required for these purposes is not accurately known, however, but is probably so small that it will be more or less entirely offset by the heat which will be liberated during the combination of the lime with the silica and alumina. We may, therefore, without sensible error, regard the total heat theoretically required for the production of a barrel of Portland cement as being that which is necessary for the dissociation of 450 pounds of lime carbonate. With coal of a thermal value of 13,500 B. T. U., burned with only the air supply demanded by theory, this dissociation will require 25½ pounds of coal per barrel of cement, a fuel consumption of only 6.6 per cent.

Losses of Heat.

In practice, however, heat is lost in a number of ways, and the fuel consumption is immensely greater than is theoretically called for. The more important ways in which heat is lost are as follows:

(1) The kiln gases are discharged at a temperature much above that of the atmosphere, ranging from 300 deg. to 2,000 deg. F., according to the type of materials used and the length of the kiln. (2) The clinker is discharged at a temperature varying from 300 deg. to 2,500 deg. F., the range depending, as before, on materials and the length of the kiln. (3) The air supply injected into the kiln is always greater, and usually very much greater, than that required for the perfect combustion of the fuel, and the available heating power of the fuel is thereby reduced. (4) Heat is lost by radiation from the ends and exposed surfaces of the kiln. (5) The mixture, in plants using a wet process, carries a high percentage of water, which must be driven off.

It is evident, therefore, that the amount of fuel actually necessary for the production of a barrel of cement is much above that required by theory.

Actual Fuel Requirements and Output.

Rotary kilns are nominally rated at a production of 200 barrels a day per kiln. Even on dry and easily clinkered materials and with good coal, however, such an output is not commonly attained with a 60-foot kiln. Normally, a 60-foot kiln working on a dry mixture will produce from 160 to 180 barrels of cement each day of twenty-four hours. In doing this, if good coal is used, its fuel consumption will commonly be from 120 to 140 pounds of coal per barrel of cement, though it may range as high as 160 pounds, and, on the other hand, has fallen as low as 90 pounds. An output of 175 barrels a day, and with a coal consumption of 130 pounds per barrel, may therefore be considered as representing the results of fairly good practice on dry materials with a 60-foot kiln. In dealing with a wet mixture, which may carry anywhere from 30 to 70 per cent of water, the results are more variable, though always worse than with dry materials. In working a 60-foot kiln on a wet material, the daily output may range from 80 to 120 barrels, with a fuel consumption of from 150 to 250 pounds per barrel. Using a longer kiln, partly drying the mixture and utilizing waste heat, will of course improve these figures materially.

When the heavy Western oils are used for kiln fuel, it may be estimated that 1 gallon of oil is equivalent in the kiln to about 10 pounds of coal. The fuel consumption, using dry materials, will range between 11 and 14 gallons of oil per barrel of cement; but the daily output is always somewhat less with oil fuel than where coal is used.

Natural gas in the kiln may be compared with good Pennsylvania coal by allowing about 20,000 to 30,000 cubic feet of gas as equivalent to a ton of coal. This estimate is, however, based upon too little data to be as close as those above given for oil or coal.

Effect of Composition on Burning.

The differences in composition between Portland-cement mixtures are very slight if compared, for example, to the differences between various natural cement rocks. But even such slight differences as do exist exercise a very appreciable effect on the burning of the mixture. Other things being equal, any increase in the percentage of lime in the mixture will necessitate a higher temperature in order to get an equally sound cement. A mixture which will give a cement carrying 59 per cent of lime, for example, will require much less thorough burning than would a mixture designed to give a cement with 64 per cent of lime.

With equal lime percentages, the cement carrying high silica and low alumina and iron will require a higher temperature than if it were lower in silica and higher in alumina and iron. But, on the other hand, if the alumina and iron are carried too high, the clinker will ball up in the kiln, forming sticky and unmanageable masses.

Character of Kiln Fuel.

The fuel most commonly used in modern rotary kiln practice is bituminous coal, pulverized very finely. Coal for this purpose should be high in volatile matter and as low in ash and sulphur as possible. Russel gives the following analyses of West Virginia and Pennsylvania coals used at present at various cement plants in Michigan:

Analyses of Kiln Coals.

	1	2	3	4
Fixed carbon	56.15	56.33	55.82	51.69
Volatile matter	35.41	35.26	39.37	39.52
Ash	6.36	7.06	3.81	6.13
Moisture	2.08	1.35	1.00	1.40
Sulphur	1.30	1.34	.42	1.46

The coal as usually bought is either "slack" or "run of mine." In the latter case it is necessary to crush the lumps before proceeding further with the preparation of the coal, but with slack this preliminary crushing is not necessary, and the material can go directly to the drier.

Drying Coal.

Coal as bought may carry as high as 15 per cent of water in winter or in wet seasons. Usually it will run from 3 to 8 per cent. To obtain good results from the crushing machinery this water must be driven off. For coal drying, as for the drying of raw materials, the rotary drier seems best adapted to American conditions. It should be said, however, that in drying coal it is usually considered inadvisable to allow the products of combustion to pass through the cylinder in which the coal is being dried. This restriction serves to decrease slightly the possible economy of the drier, but an evaporation of 6 to 8 pounds of water per pound of fuel coal can still be counted on with any good drier. The fuel cost of drying coal containing 8 per cent of moisture, allowing $2 per ton for the coal used as fuel, will therefore be about 3 to 4 cents per ton of dried product.

Pulverizing Coal.

Though apparently brittle enough when in large lumps coal is a difficult material to pulverize finely. For cement-kiln use, the fineness of reduction is extremely variable. The finer the coal is pulverized the better results will be obtained from it in the kiln, and the poorer the quality of the coal the finer it must be pulverized. The fineness attained in practice may therefore vary from 85 per cent, through a 100-mesh sieve, to 95 per cent or more, through the same. At one plant a very poor but cheap coal is pulverized to pass 98 per cent through a 100-mesh sieve, and in consequence gives very good results in the kiln.

Coal pulverizing is usually carried on in two stages, the material being first crushed to 20 to 30 mesh in a Williams mill or ball mill, and finally reduced in a tube mill. At many plants, however, the entire reduction takes place in one stage, Griffin or Huntington mills being used.

Total Cost of Coal Preparation.

The total cost of crushing (if necessary), drying,

and pulverizing coal, and of conveying and feeding the product to the kiln, together with fair allowances for replacements and repairs and for interest on the plant, will probably range from about 20 to 30 cents per ton of dried coal, for a 4-kiln plant. This will be equivalent to a cost of from 3 to 5 cents per barrel of cement. While this may seem a heavy addition to the cost of cement manufacture, it should be remembered that careful drying and fine pulverizing enable the manufacturer to use much poorer, and therefore cheaper, grades of coal than could otherwise be utilized.

Clinker Grinding.

The power and machinery required for pulverizing the clinker at a Portland cement plant using the dry process of manufacture are not much more than those needed for pulverizing the raw materials. This may seem at first sight improbable, for Portland cement clinker is much harder to grind than any possible combination of raw materials; but it must be remembered that for every barrel of cement produced about 600 pounds of raw materials must be pulverized, while only a scant 400 pounds of clinker will be treated, and that the large crushers required for some raw materials can be dispensed with in crushing clinker. With this exception, the machinery for treating the raw material and that for treating the clinker of a dry process Portland cement plant are usually almost duplicates.

The difficulty, and in consequence the expense, of grinding clinker will depend in large part on the chemical composition of the clinker and on the temperature at which it has been burned. The difficulty of grinding, for example, increases with the percentage of lime carried by the clinker, and a clinker containing 64 per cent of lime will be very noticeably more resistant to pulverizing than one carrying 62 per cent of lime. So far as regards burning, it may be said in general that the more thoroughly burned the clinker, the more difficult it will be to grind, assuming that its chemical composition remains the same.

The tendency among engineers at present is to demand more finely ground cement. While this demand is doubtless justified by the results of comparative tests of finely and coarsely ground cements, it must be borne in mind that any increase in fineness of grinding means a decrease in the product per hour of the grinding mills employed, and a consequent increase in the cost of cement. At some point in the process, therefore, the gain in strength due to fineness of grinding will be counterbalanced by the increased cost of manufacturing the more finely ground product.

The increase in the required fineness has been gradual but steady during recent years. Most specifications now require at least 90 per cent to pass a 100-mesh sieve, a number require 92 per cent, while a few important specifications require 95 per cent.

Addition of Gypsum.

The cement produced by the rotary kiln is invariably naturally so quick-setting as to require the addition of sulphate of lime. This substance when added in quantities up to 2½ or 3 per cent, retards the rate of set of the cement proportionately, and appears to exert no injurious influence on the strength of the cement. In amounts over 3 per cent, however, its retarding influence seems to become at least doubtful, while a decided weakening of the cement is noticeable.

Sulphate of lime may be added in one of two forms, either as crude gypsum or as burned plaster. Crude gypsum is a natural hydrous lime sulphate, containing about 80 per cent of lime sulphate and 20 per cent of water. When gypsum is calcined at temperatures not exceeding 400 deg. F., most of its contained water is driven off. The "plaster" remaining carries about 93 per cent of lime sulphate, with only 7 per cent of water.

In Portland cement manufacture either gypsum or burned plaster may be used to retard the set of the cement, but gypsum is universally employed in the United States. This is merely a question of cost. It is true that to secure the same amount of retardation of set it will be necessary to add a little more gypsum than burned plaster, but gypsum is much cheaper than burned plaster.

The addition of the gypsum to the clinker is usually made before it has passed into the ball mill, comminuter, or whatever mill is in use for preliminary grinding. Adding it at this point insures much more thorough mixing and pulverizing than if the mixture were made later in the process. At some of the few plants which use plaster instead of gypsum the finely ground plaster is not added until the clinker has received its final grinding and is ready for storage or packing.

HOW THEY MAKE THE TIME TABLES.*

By M. C. Miller.

As a result of the travel habit, many persons can now determine from time tables, for themselves, what service is afforded by any railroad. Seldom, however, does a traveler stop to think—much less realize—what is involved in arranging a comprehensive schedule of trains. It is a complex problem, at best, to fix the schedules on a large system so that all will dovetail together and work smoothly when in practice, and, of course, much more intricate if operations are confined to a single track, when all trains must be arranged to meet and pass on station sidings, and that, too, without undue loss of time on the part of either. In addition, the schedules must be arranged so as to avoid a conflict at terminals and particularly the largest ones.

The general passenger or freight agent may recommend changes in service or the running of additional trains, but when any change is determined upon by the management, the ultimate adjustment of the time table devolves upon the superintendent or chief train dispatcher.

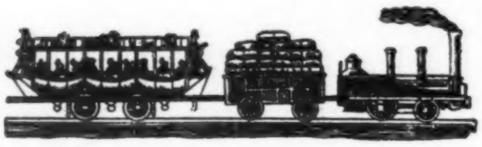
Referring first to the passenger service, it is necessary to start the principal trains at such intervals as will accommodate the greatest number of through passengers, and at the same time arrange to have them reach terminal stations at convenient, seasonable hours, whether connecting trains are desired or not, as no one wishes to reach a destination or have to change cars very late at night or too early in the morning. Local or accommodation trains are obliged to keep out of the way of through trains, but, if unduly delayed thereby, their passengers chafe at such detention, so that local trains are frequently given preference to the track on many lines that have a heavy suburban travel, if through trains are late.

For systematic convenience, all regular trains are designated by numbers. If odd ones are used west or north-bound, even numbers cover trains moving in the opposite direction.

summer, over a portion of the White Mountains division of the Boston & Maine Railroad, an important link in one of the principal routes between Boston and Montreal all the year, while through trains to and from New York use another part of it during the summer. It connects with four other divisions of the Boston & Maine Railroad and three foreign roads, hence it has to care for considerable through, as well as local, travel and traffic; it has so many junctions that arranging satisfactory service and connections for the summer travel would be no easy matter if a radical readjustment was required, and it is a single track line, with heavy grades, both north and south of Woodsville.

Suppose it has been decided to put on a new through train daily, between Bretton Woods and New York, same to be known as Nos. 38 and 21; a conference is held, at which all interested division superintendents are present. After the character of the train has been determined, each superintendent states how much time will elapse before he can deliver it at the proper junction point, and then the time of arrival at, and departure from, each terminal station is fixed at what is considered the most suitable hour. It would be shown that, in order to reach New York at the agreed time and also connect with various other trains at the several

INLAND ROUTE.



FOR NORTHERN AND SOUTHERN TRAVELLING.

The Richmond, Fredericksburg and Potomac Rail Road Company, in connection with the other Rail Road anc Steamboat Companies, on the route, have adopted the following Schedule, by which the daily mail is now carried.

(NORTHWARD DIRECTION.)

Leave				Arrive at			
Blakely, N. C.....at	5	o'clock,	P. M.	Petersburg,. .....at	10	o'clock,	P. M.
Petersburg,.......“	12	“	A. M.	Richmond, ...“	4	“	A. M.
Richmond,.......“	4½	“	A. M.	Washington,.....“	6	“	P. M.
Washington, ...“	7½	“	P. M.	Baltimore,.......“	10	“	P. M.
Baltimore, ...“	6	“	A. M.	New York,.. ...“	11	“	P. M.

(SOUTHWARD DIRECTION.)

Leave				Arrive at			
New York,.......at	4	o'clock,	P. M.	Baltimore, ...at	3	o'clock,	P. M.
Baltimore,........“	5	“	P. M.	Washington, ...“	8	“	P. M.
Washington,.....“	10	“	P. M.	Richmond,.......“	2	“	P. M.
Richmond, ...“	3	“	P. M.	Petersburg, ...“	7	“	P. M.
Petersburg, ...“	1½	“	A. M.	Blakely,.........“	7	“	A. M.

The whole time required between *Blakely* and *New York*, being Northwards, 54 hours; Southwards, 57 hours. Between *New Orleans* and *New York*, Northwards, 12 days and 13 hours; Southwards, 13 days and 8 hours. Of the whole distance between Blakely and Baltimore, 126 miles is travelled upon Rail Roads, and 50 miles by Steamboat.

The Stage Travelling, which is conducted by Messrs. J. Woolfolk & Co. and Messrs. J. H. Avery & Co. in the handsomest manner, being now only 67 miles, is becoming rapidly reduced by the extension of this Rail Road.

☞ Passengers are never in danger of delay, preference being given to such as enter and continue on the line.

By arrangements which this company is making, Passengers, with their baggage, will be conveyed to and from the Depot, without charge. On the Rail Road, a coach will be especially appropriated to Northern and Southern Travellers; and in general, the Company's Agents will adopt all measures calculated to expedite and facilitate their journey.

Carriages and Horses are safely and expeditiously transported; enabling those travelling in them with the additional use of the Potomac Steamboat, and the Petersburg Rail Road, to accomplish, without fatigue to their horses, the journey between Washington and Blakely, N. C. in two days.

☞ The Mail Train leaves Richmond at 4½ o'clock, A. M.; returning leaves the North Anna at 12 o'clock, M. The alternate Trains for Passengers and Freight, leave the North Anna at 7 o'clock, A. M. and 4 P. M.; and Richmond at 9 o'clock A. M. and 1 P. M.

All possible care will be taken of baggage, but it will be carried only at its owner's risk.

Rail Road Office, Richmond, May 30, 1836.

AN OLD-FASHIONED TIME TABLE

With these fundamental principles in mind, coupled with an intimate knowledge of the profile and other characteristics of the road, the prospective schedule, instead of being laboriously (and perhaps erroneously) figured out, is first arranged on a board or chart. If the former is used, the movements are represented by colored cords, kept in place with pins, to facilitate readjustment at will. The charts are similar in general design, but on a smaller scale, and, as the movements represented thereon are tentatively made in pencil, subsequent necessary changes can be easily made. On some double-track roads, however, it is customary for experienced men to figure the schedules first and then prove them by means of the board or chart just mentioned.

As will be seen, the time from twelve o'clock midnight to the next midnight is divided into spaces of five minutes each by perpendicular lines, and the stations are shown in geographical order opposite horizontal lines that are proportionally as far apart as the stations themselves. The latter ruling necessarily must be adapted to the needs of each road and be accurately drawn to a certain scale, or the contemplated movements will not work out properly in actual practice.

The accompanying illustration shows a section of such a chart, with scheduled train movements between the hours of 9 A. M. and 4 P. M., as prepared for last junction points *en route*, the southbound train (No. 38) could leave Fabyans at 9 A. M. and reach Wells River (across the Connecticut River from Woodsville) for delivery to the Passumpsic division at 10:25. A train of this character requires the right of way during this hour and twenty-five minutes, and, concurrently with the apportionment of this time, the question is presented of what rearrangement of other trains is necessary, practicable, and desirable, with corresponding consideration of the situation as affecting the proposed new northbound train.

Assuming other scheduled trains were moving substantially as indicated, an inspection of the chart would show that provision must be made to meet and pass local freight train No. 11 and accommodation passenger train No. 303, at suitable points, and the same situation would have to be considered in arranging for the movement of the Boston express, No. 40. The train movements are much more numerous and complicated over that portion of the road between Woodsville and Concord, and in arranging the schedule for a division of this character, some time must be allowed for meals at Plymouth, while the 1 and 5-10 per cent grade for ten miles south and eighteen miles north of Glencliff reduces the speed as trains approach that station.

By depicting first the through passenger trains, then

* The New York Evening Post.

the local or accommodation trains, followed by the through freights and local or way freights, while concurrently considering the character and equipment of each train, coupled with grades, length of passing sidings at stations, and a knowledge of what results have been accomplished by trainmen in actual practice, the necessary meeting points are established, as shown by the intersecting lines. The responsible official is also enabled to secure what might be considered a bird's-eye view of the entire situation on his division at any given time of day, as each scheduled train appears in its proper relation to all others, although, at first sight, the result appears to indicate a severe and concentrated electrical storm.

The numbers shown against each line on the chart are for convenience in tracing the respective train movements. Other through freight trains, called "extras," are run without appearing on the chart, as the volume of traffic from day to day may warrant, so that the track is really occupied to a greater extent than indicated. As may be inferred from their slow progress, Nos. 22 and 13 are local freight trains, that perform considerable switching at stations *en route.*

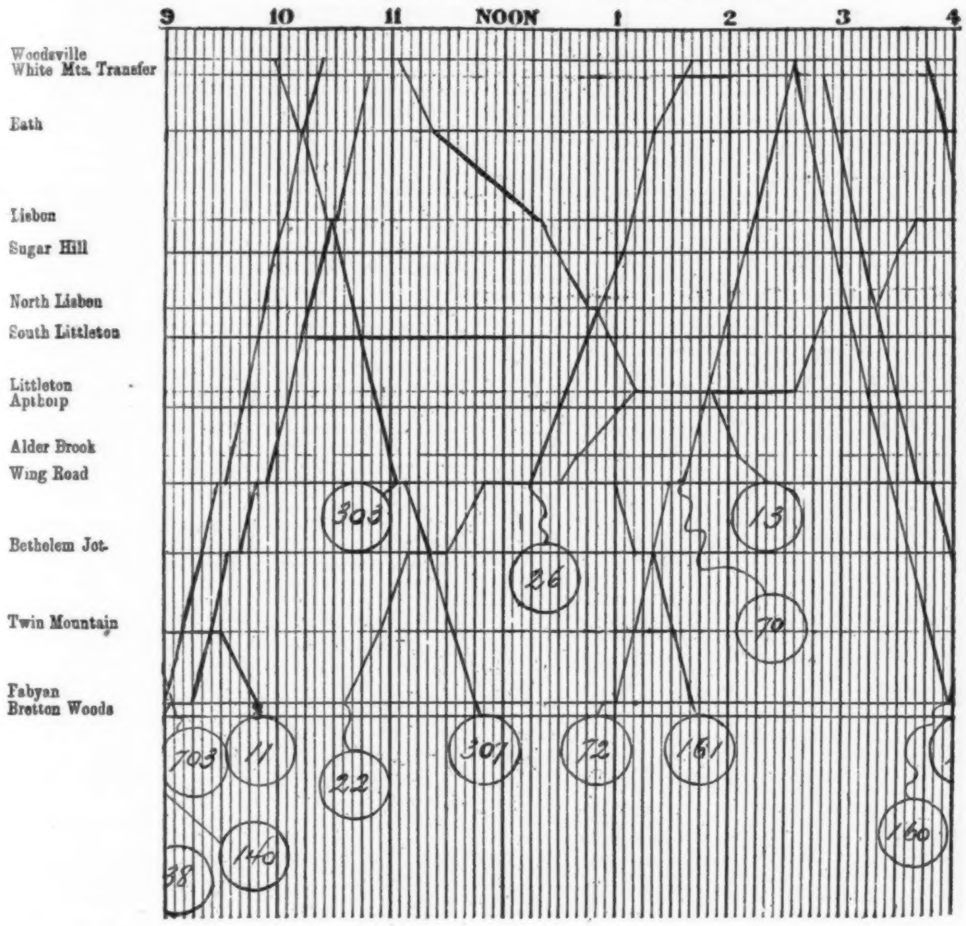
If cars are to be taken on or off, or large quantities of baggage, mail, or express matter are regularly handled by certain trains at specific points, allowance must be made therefor, as it is much more satisfactory to have a train run according to schedule, even if the time consumed is as great, than to have it often or always late because of insufficient time in which to do the work required.

In this connection, those who are disposed to find fault with the management or trainmen whenever a train is delayed, may be interested to learn that the conductor makes a special report to the superintendent each time his train is delayed on the road or at stations, giving all the circumstances in detail. For example, these blanks classify the detention, if caused by a locomotive failure, under several heads, viz., hot boxes or bearings, hot or broken eccentrics, air-brake failures, broken side or main rods, and steam failures. The latter includes bad coal, bad fire, dirty flues, improper firing, leaky flues, etc. A careful investigation of each detention is made, and necessary repairs are effected as quickly as possible; but, if the detention was caused by an engine failure, such as improper firing, dirty flues, etc., the enginemen are sure to be called upon for an explanation. These reports are recorded, and, with this system of surveillance in vogue, every man who wishes to remain in the service is bound to do his best, or he is sure to be soon superseded by one who will render satisfactory service.

While rearrangements may occur at any time, there are usually but two general changes each year; one, to care for the summer travel, and the other to cover the winter and spring months, when freight traffic predominates.

Conditions on the principal roads are now such that additional trains can seldom be run at times when the track is comparatively free, because, at such times, there would probably also be but few, if any, passengers in waiting at important stations,

WHITE MOUNTAINS DIVISION—SCHEDULE No. 15.



PORTION OF CHART BY MEANS OF WHICH A DIVISION TIME TABLE IS PREPARED.

Each additional or annulled train results in more or less disorder along the line. When the eighteen-hour trains between New York and Chicago were inaugurated, a material rearrangement in some portions of the schedule was necessitated by the long, fast, run and superior character of the service.

On double track roads the same principles govern, except, of course, that trains running in opposite direction do not affect each other, as they can pass anywhere; hence, generally speaking, only those moving in one direction require concurrent consideration—for time-table purposes.

In order not to give too many cars and locomotives at either end of the line, as well as accommodate the public, it is customary to run the same number of trains in both directions although, under certain conditions, an occasional return movement may be made out of service, or "deadhead," as it is termed.

After the chart has been completed, the figures indicated thereby are copied (with characters showing at what stations stops are to be made and what days each train is to run), in shape for printing the official time tables that are furnished to enginemen, conductors, and other interested employes. Ample notice has to be given, that all concerned may familiarize themselves therewith, prior to the date on which the new schedule is to become effective, and all employes are enjoined to study it carefully and be sure that every change in time or running rules is noted and thoroughly understood.

As soon as the operating time table has been printed and, upon careful comparison, found to be correct, a copy is furnished to the general passenger agent. The passenger or advertising department then notifies newspaper publishers along the line of impending changes and prepares folders showing all the passenger train service, omitting the time at stations where stops are not made, but giving additional information required by the public, such as stop-over rules, dining, parlor, or sleeping car service and charges; whether trains run daily or otherwise; a description of the equipment run on the principal through trains, and a condensed schedule of the service afforded by connecting roads to and from most junction points.

Although these comprehensive folders are very popular, especially when accompanied, as many of them are, by a good map, the men engaged in preparing them are constantly striving to improve them in every way that experience and ingenuity suggest. Originally they were printed on sheets of paper about a yard long, which made them unwieldy to handle when open, and the Union Pacific is credited with having been the first road to devise the very convenient book form that is now generally used for the purpose.

The Union Pacific road has also introduced various innovations in its folders from time to time. For instance, one excellent and decided innovation was first made when its December, 1903, issues were put out, showing the condensed schedule of its through trains. By using three columns on a page, under the number and distinctive name of each train, and showing in the first the time of departure from, and arrival at, the principal stations, in the second the character of the equipment employed, and in the third the point of origin and destination of each car hauled by that particular train, desirable simplicity was at once secured; the whole situation is revealed to a prospective traveler at a glance.

The process of evolution that time tables have undergone during the past seventy years is well illustrated by the reproduction of one published May 30, 1836, by the Richmond, Fredericksburg & Potomac Railroad. This is believed to be the oldest regular railway schedule in America. Two of these originals were found in the company's archives, and one of them was exhibited in the Transportation Building at the World's Fair in Chicago and then donated to the Field permanent museum in that city. This company was chartered in 1834, hence it is one of our oldest railway corporations. Probably every road that has been built since that time has expanded by leasing, or consolidating with, other lines, under a new name, or gone through a receivership and consequent reorganization, but, in this respect, the Richmond, Fredericksburg & Potomac Railroad is in a class by itself, as it has continued successfully to operate substantially its original mileage under its original charter.

The plates for the maps in the best folders constitute the principal first cost. It is not generally known that representative American lines frequently receive applications for their folder maps from abroad for educational purposes; in fact, a map showing the through route to Asia, which was prepared by the New York Central passenger department some time ago, has been much sought by schools and representatives of this and other governments, as being the most complete and up-to-date of its kind in the world.

The railway and some steamship companies print increased quantities of time tables each year, many of which are handsome in design and clear and concise in type and text, as well as beautifully illustrated. Those that contain descriptions of some summer and winter resorts or tours are often printed in artistic colors, and they are as well written and carefully edited as many magazines. Some of those issued by the trunk lines cost $25 per 1,000, although they are for free distribution. Elaborate and well-illustrated folders would cost considerably more, hence the roads hardly "break even" when applicants are asked to send one or more postage stamps for them.

In the largest cities, the distribution of these folders has become quite a business in itself. Approximately four million of these time tables were given away during 1905 in New York city alone. Each month, in this city, the Pennsylvania Railroad distributes 70,000 folders, the New York Central circulates 65,000, the Central Railroad of New Jersey 50,000, and the New Haven and Lackawanna 20,000 each, with others in proportion, while, among the Western roads, the Burlington route distributed nearly 2,500,000 throughout the country last year, the Chicago & Northwestern issued approximately 2,000,000, and the Union Pacific put out nearly as many as the Northwestern.

At first, time schedules, with advertisements, were printed on huge framed posters that were hung on the walls of hotel offices and other public places, and most of them were the reverse of artistic. When "Jim" Fisk was a constant patron at the Broadway Central Hotel, as it was a common practice elsewhere, he hung numerous Erie Railroad placards in the public rooms, and, not to be outdone, other railroad agents naturally followed suit. The result can be better imagined than described, and the proprietor finally cleared them all out, after remarking, "I paid $1,000 to decorate this office, and haven't had a chance to see what I got for my money." As many others began to feel the same way, that form of time table has been almost entirely superseded by the much more convenient folder, and the framed time table is not now obtrusive, even in station waiting-rooms.

With the advent of, and demand for, folders, each road attended to its own distribution, but this was found to be quite expensive, and companies were formed to make a systematic distribution in the principal cities. The pioneer company in this city has branches in Boston, Philadelphia, Baltimore, and Washington, and its automobile distributing car in this city has been quite noticeable for some time past. Prior to starting this systematic distribution, the companies purchased and placed suitable racks, containing 110 spaces, for as many different issues of time tables, in all the large hotels, and their operations became of international scope. A few years ago it was seldom that an English time table could be found in a New York hotel, but, under the arrangement just mentioned, London & North-Western Railway and other foreign folders may be found in hotel reading-rooms beside those issued by American roads, and the folders of the leading American roads may now be found in the principal European hotels.

Just prior to the Russo-Japanese war, a dispute about the Siberian Railroad arose between two men at a New York hotel. One of them called a boy and said:

"Go to the rack and get me a time table of the Siberian Railroad in Russia."

His companion laughed and said: "I'll bet you a dinner you don't get it."

Inside five minutes, however, the boy came back with the desired schedule.

The nature of gravitation is as unknown as the nature of life itself. We know how it acts, and that this action is millions of times quicker than light, but that is all, and the one who unravels the mystery will deserve to rank with the greatest of discoverers.

THE MECHANICS OF LUMINOSITY.

SOME Continental critics have been rather inclined to ridicule a certain practice, almost confined to the British school of scientific thought, that is to say, the practice of picturing a mechanism capable of reproducing the phenomena of molecular physics, and of reasoning about this arbitrary concept, instead of confining themselves to a mere study of certain differential equations. Such critics have, it is true, been to a large extent silenced by Helmholtz's confession that the method had led to remarkable results in the way of the advance of discovery, and it has, moreover, the further advantage of permitting a plain man, ignorant of higher mathematics, to obtain some idea as to the nature of the phenomena in question.

Prof. J. J. Thomson, perhaps the leading living physicist, possesses this characteristic of the British school of science in a marked degree; and for this reason his Friday-evening lectures at the Royal Institution are of especial interest to those who, though incapable of following in their entirety the remarkable series of researches by which the Cavendish Laboratory at Cambridge has become a sort of Mecca for the student of physics, are nevertheless anxious to gather some gleanings from the fruits of these important investigations. Nothing could better serve this end than the highly suggestive lecture on "Some Applications of the Theory of Electric Discharge to Spectroscopy," delivered last Friday evening at the Royal Institution by Prof. Thomson. In opening his discourse, he stated that when an electric current passed through a gas, the color of the light and the character of the spectrum depended not only on the chemical nature of the gas, but also on the nature of the current, the spectrum being often entirely different with an arc discharge from what it was with a spark discharge. Moreover, in certain cases the color of the spectrum was entirely different in different parts of one and the same tube. This was shown by Prof. Thomson with a Plucker tube containing air, the peculiarity of the tube being that it consisted of two wider portions connected by a capillary channel. The color of the glowing gas in this narrow channel was entirely different from its color in the bulbs. Recent investigations, he proceeded, had thrown a good deal of light on what actually took place when a gas became luminous by the passage of a discharge, and he intended that evening to explain in what manner the different effects observed were accounted for by theory, and a comparison of the difference in the nature of the luminosity produced with different voltages threw, moreover, a good deal of light on the generation of spectra. These researches had, he remarked, been much facilitated by the observation that when lime or barium oxide was used as the cathode, an extraordinary number of negative corpuscles were emitted at all temperatures of the cathode. Thus, using lime, a P.D. of only 18 to 100 volts would give a very bright discharge, and alterations of the current strength and potential difference within a very wide range were thus much easier to make than with other substances as cathode. The apparatus used was that shown in Fig. 1. The lime here was deposited on a thin platinum wire carried by stout leads, as shown. An independent current passing through these leads served to keep the platinum wire red-hot, while a third wire led from the center of the cathode thus formed to the negative terminal. A bulb of this kind could also, he stated, be used as a rectifier, since the current would only pass through the tube when the lime was the cathode. The discharge in the tube shown by Prof. Thomson was blue, and was very sensitive to the action of a magnet, which not only deflected the moving particles, but concentrated them along the line of force.

A peculiarity of the discharge, he pointed out, was the abruptness with which luminosity made its appearance. In the laboratory a difference of 1-100 volt was sufficient to cause the tube to pass from perfect darkness to quite a bright discharge. The light therefore made its appearance instantly, and did not start as a faint glow, and gradually get brighter. This fact he considered was most important in the mechanics of luminosity, and the conclusion he had come to was that owing to the bombardment of the atoms of the residual gas by the flying corpuscles, the internal energy of the atoms was increased. This increase of energy required time for it to be radiated off, and if the impacts followed each other sufficiently rapidly, the value of the internal energy was raised to a critical value at which the equilibrium became unstable, when the atom itself flung off a corpuscle, and the shock of the discharge threw the rest of the atom into vibration, giving rise to light, which, therefore, was the direct consequence of atomic instability.

In confirmation of this it was found that the negative corpuscles emitted when Röntgen rays fell on a metal had the same penetrative power whatever the intensity of the Röntgen rays, whereas were they dragged out of the atom by the electric field of the rays, their speed and penetrative power should increase with the strength of the radiation. This was not the case, since an increase in the strength of the Röntgen rays merely increased the number of corpuscles liberated, and did not increase their penetrative power. Lenard had further shown that the corpuscles expelled on letting ultra-violet light fall on metals had a velocity quite independent of the intensity of the light, which is what would be expected were the instability set up in the atom the real cause of the expulsion, while the rays or the ultra-violet light merely served as a sort of trigger.

When a corpuscle struck an atom in a vacuum tube, the internal energy of this atom was increased, and might, as stated, accumulate to a critical value. As soon as the gas became luminous there was an enormous increase in the current, a difference of one-hundredth of a volt sometimes causing a sixty-fold increase in the current. The stage at which luminosity set in depended much on the temperature, the luminous point being reached with, say, 55 volts at high temperatures and 100 volts at low. An increase in the current density, moreover, tended to promote the luminous discharge, since each atom encountered more corpuscles in a given time. A single collision was insufficient to render an atom luminous. There must be many. Hence, as the action of a magnet tended to concentrate the discharge, a tube would become luminous at a lower P.D. when a magnet was held near it than when the magnet was absent. If single collisions sufficed to render an atom luminous, the intensity of the light should increase proportionately to the current; but this was not the case, the increase of luminosity being much more rapid than the increase in the number of cathode particles.

Hence, to get luminosity, we must, Prof. Thomson said, be able to raise the internal energy of the atom to a certain critical value, and the atom must not part with the energy thus received too rapidly, or this critical value would never be reached. Calling the rate at which the atom received energy α, and assuming that the rate at which it radiated off energy was proportional to its total internal energy, the rate at which this energy increased with lapse of time was given by the expression—

$$\frac{dE}{dt} = \alpha - \beta E;$$

and the total internal energy at any time was thus

$$E = \frac{\alpha}{\beta}\left(1 - \varepsilon^{-\beta t}\right).$$

The maximum value which E could reach after the lapse of infinite time was $\frac{\alpha}{\beta}$. Typical curves showing E were represented in Figs. 2 and 3.

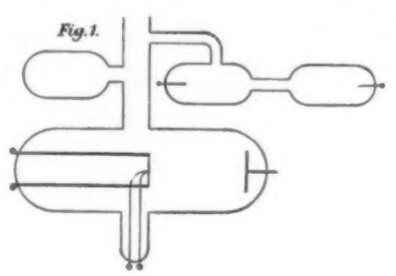


Fig. 1.

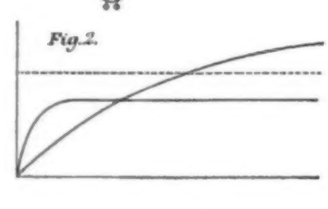


Fig. 2.

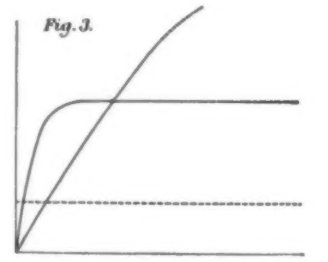


Fig. 3.

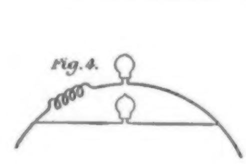


Fig. 4.

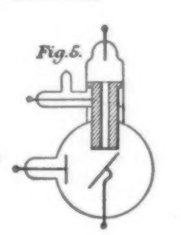


Fig. 5.

It appeared, Prof. Thomson continued, that there were two radiating systems in an atom. One of these was a poor absorber of energy from the corpuscles, and also a poor radiator, while the second was both a good absorber and a good radiator, so that the fraction $\frac{\alpha}{\beta}$ for this second system was less than for the first. For either system to give light a certain critical value of E must be attained, which for simplicity might be taken as the same for both systems.

Suppose, then, that in Fig. 2 the rate at which energy is supplied was small, but the supply was long-continued, and let also the dotted line represent the critical value for E at which luminosity appeared; then the upper curve represented the case of the poor absorber and poor radiator, which would, as represented, ultimately exceed this critical value, while the good radiator and good absorber represented by the other curve would not reach it. If, however, the rate at which energy was supplied were increased, then we obtained the condition of affairs represented in Fig. 3, where both curves exceeded the critical value, and the good radiator did so first. If, moreover, the supply of energy ceased soon after this latter event, it would be seen that the poor radiator and absorber would not have time to reach the critical state, so that the spectrum corresponding to the second vibrating system would alone be seen.

As an illustration, Prof. Thomson suggested that E should be taken to represent a man's capital and α his income, and that the amount he spent was a constant fraction of E. Then the poor absorber and radiator corresponded to a man receiving a small salary, but also spending little—say, at the rate of one-thirtieth of his total capital existing at any time. If his salary were 1,000*l.* per annum, and a capital of 20,000*l.* would make him a "shining light," he would, if his salary lasted long enough, reach this limit, and, if he lived an infinite time, might accumulate 30,000*l.* If, on the other hand, a man's salary was 5,000*l.* per annum, and he spent at the rate of one-third of his capital, he could never, no matter how long he lived, accumulate more than 15,000*l.*, and hence would fail to reach the position of a "shining light." Suppose, however, that times changed, and the salaries became four times as great, but lasted a much less time; then the second man would attain the desired standard very quickly, while, if the good times were sufficiently short, the other might never reach it at all.

In these considerations was, he thought, to be found a clue to the passage from arc to spark spectra, and also of the influence on spectra of inductance and capacity. With the arc discharge one got a large steady current, the average value of which was practically the same as the maximum. With the spark discharge the average value of the current was small, but the maximum value, though it lasted for only a very short time, might be very great. Returning to the analogy just given, the saving man was favored by the arc, and the man with large earnings and large expenditure by the spark discharge. Again, where the discharge passed through a capillary tube the current density was great, and therefore the internal energy of an atom encountered might be increased by the numerous impacts, so that the second system was put into vibration; while in the wider parts of the tube only the first system alone reached this critical stage. The spectrum of the discharge in the two portions would thus be different.

Similar considerations applied to the alteration produced in spectra by varying the capacity and inductance in the spark circuit. An increase in capacity increased the maximum rate at which work was done in the circuit, while self-induction had a precisely contrary effect, so that with a large inductance the discharge approximated to the arc type. This was well shown by vacuum tubes containing argon, which, as discovered by Sir William Crookes, gave a light of an entirely different color, according to the relative inductance and capacity of the spark-circuit in which they were included. Prof. Thomson showed that when such a tube was connected up to a spark-circuit of large capacity, but small inductance, it glowed with a red light, while the addition of a large inductance to the circuit caused the color of the discharge to alter to a bright blue; similarly, a neon tube glowed yellow when the inductance in the circuit was small, and green when it was large. To illustrate the kind of action which was held to be responsible for this change the lecturer exhibited the piece of apparatus shown diagrammatically in Fig. 4.

Hence, a red and a blue lamp were arranged in parallel on the same source of supply. The red-lamp branch has a large inductance and a low resistance, while the blue lamp formed part of a circuit of high resistance and low inductance. Concerning the device with a source of continuous current, the red lamp alone lit up; but on an alternating circuit this remained dark, and the blue lamp was the one which glowed.

On these lines he thought it was possible to account for the double spectrum of argon without assuming any decomposition of the atom of the gas. Both of the vibrating systems postulated were interior to the atom, and either one or the other would be set in vibration according to the character of the discharge. It would, he continued, be of great interest to watch the behavior of the gas while the inductance was slowly increased, and to note whether the change of spectrum took place gradually, the new one making its appearance line by line; or whether all the lines of the new spectrum appeared simultaneously. Some experiments by Prof. Wood had a bearing on this. In these the luminosity of sodium vapor was excited by means of light, and the color of the spectrum was found to depend on the wave-length of the incident light. With a certain wave-length a spectrum containing certain lines was observed. Altering the wave-length of this incident light, the spectrum disappeared entirely, until by continuing the alteration an entirely different spectrum suddenly made its appearance, the whole of the lines of which appeared simultaneously. On the hypothesis made this was to be expected. Either vibrating system, when it reached the critical point, taking simultaneously all its possible modes of vibration.

It should further be noted that the rate at which the atom received energy by impact depended also on the nature of the projectiles as well as on their kinetic energy. If these were moving corpuscles, there would also be a particular speed at which the amount of energy transferred to the vibrating system was a maximum. The quicker the natural period of this system the higher was the speed at which the corpuscle must move for the maximum transference of energy to take

place. The speed of the corpuscles was dependent on the pressure in the tube, being highest when this pressure was low, so that a change of pressure might give rise to a change of spectrum.

Further, if, instead of bombarding the atom with corpuscles, the projectiles were bodies of atomic dimensions, the spectrum produced was very different. For this purpose the lecturer made use of the apparatus represented in Fig. 5, where there is shown a metallic plug pierced in the center, and which by means of the connecting wire shown could be made, at will, either an anode or a cathode. When the latter, the return flow of positive particles of atomic dimension passed down through the plug and incited the luminosity of a layer of lithium salts deposited on the inclined plate shown, which then gave a red light. If, however, the upper terminal were made the cathode, the much smaller negative particles would strike the lithium salt, and the color of the fluorescence was then bluish-green. He did not know, he said, whether any effect would be produced if metallic lithium were substituted for the salts of that metal, but a similar bombardment of metallic sodium did not give rise to the spectrum of that metal, while that of its salts did. If the discharge were directed on to a layer of sodium potassium amalgam, any small particles of oxide on the surface would glow with a yellow light, while the clean metallic surface remained dark.

Summing up; on the theory set forth, luminosity was due to a critical state of the internal energy of an atom. Temperature, on the other hand, measured the energy of translation of an atom, yet a certain equilibrium must exist between this energy of translation and the internal energy; and by sufficiently increasing the energy of translation, sufficient of this might be transformed into internal energy to give rise to luminosity. The advantage of exciting luminosity by the electric method was that the energy was added, in the first place, direct to the internal energy of the atom, and equilibrium of this and the energy of translation was established by the transformation of part of this internal energy. The difference between this and the ordinary method of exciting luminosity by the raising of the temperature, the speaker compared to that between boiling a kettle by lighting a fire under it, and doing the same thing by setting the kitchen on fire.

In conclusion, Prof. Thomson showed an experiment with a tube containing a calcium electrode, which he considered threw much light on the nature of the arc. The discharge of such a tube increased as the temperature of the cathode was raised. If this discharge was sufficient, the temperature was still further augmented by the impact of the positive particles from the anode, and the temperature being thus automatically increased, the discharge finally reached a point where it formed a veritable arc.—Engineering.

THE PHYSIOLOGICAL EFFECT OF LIFE IN THE ALPS.*

ALPINE literature has a special charm; it rekindles memories of happy hours spent among the mountains, and thrills us with echoes of that intense delight in life which was the prominent characteristic of days in Switzerland. No doubt many things contribute to the pleasure which the Alps give to thousands of men and women, but one obvious and potent factor is the sense of well-being; we feel that, like the elixir of life, mountain air and scenery rejuvenate body and mind.

In the important work just published by Prof. Zuntz, Prof. Loewy, and their comrades, a scientific basis is afforded for this rejuvenating influence. The volume contains an account of an expedition undertaken expressly to carry out physiological investigations at high altitudes. Such expeditions have been frequently made, the most notable being the pioneer one of Paul Bert, the extensive one of Kronecker and his colleagues, and those which Mosso has repeatedly carried out in the Monte Rosa district. The expedition conducted by Prof. Zuntz has no doubt reaped great advantages from the study of the work of its predecessors, and the results achieved are in consequence more convincing, and from the physiological standpoint more valuable.

Since the object of the expedition was the enlargement of physiological science, the essential features of the account are of necessity somewhat technical. But the volume contains many passages which are of general interest, including an extensive historical account of earlier expeditions. There are in every one of the twenty-two chapters passages which will appeal to all those who love the Alps, for Prof. Zuntz is himself one of this fraternal band, and reveals his own enthusiasm not only by the character of the descriptive writing, but more directly by the interpolation of many beautiful Alpine illustrations. Moreover, such practical details as clothing, food and exercise are dealt with from the alpinist's point of view, and what is termed "sport" is treated in a most suggestive way.

To the majority of readers, especially if they should be medical practitioners, the most interesting portions of this really great work will be those which set forth the peculiarities of the climate in high altitudes and the influence which these peculiarities must exert, not only on vigorous athletes who climb the topmost peaks, but on the ever-increasing number of less ambitious mortals who seek the Alps in order to restore shattered health, or to check the advance of disease. In chapter xx. the benefits and dangers of life in moderately high altitudes are set forth in the light of the results of the expedition; the new basis for estimating the value of such benefit or the extent of such danger which is given in this part of the work should of itself secure the general reputation of the volume owing to its direct bearing upon some of the most important hygienic topics of the day.

It is impossible in the short space of this notice to do justice to such a comprehensive volume; but since the essence of the work lies in the physiological effects which were observed at high altitudes, and these form the basis referred to in the preceding paragraph, a brief summary of the physiological results must be attempted. In order to realize their nature, the plan of the expedition will be first described.

Two physiological professors, two assistant professors, and two younger members of the medical profession engaged in physiological research formed the personnel of the expedition. For more than twelve months each member of the party had made elaborate experiments of a preliminary character in the Berlin laboratories in order to become efficient in the quantitative work necessary for the investigation of the body metabolism. The details of the expedition were planned with great care and forethought; valuable aid was afforded by Prof. Kronecker, of Berne, and Prof. Mosso, of Turin, the most essential feature of this help being the offer of the working laboratories established in the Brienz district by Kronecker and in the Monte Rosa district by Mosso. In July, 1901, the actual work was begun at Brienz. This is situated at the east end of the lake of that name, and lies at the height of 1,857 feet; it is connected by a mountain railway with the summit of the Brienz Rothhorn (7,713 feet). At Brienz each member of the party, by strict diet and other precautions, placed himself in a condition of nitrogenous equilibrium, that is, a condition in which the quality of nitrogen assimilated from the food is equal to that excreted in twenty-four hours. After a few days the party divided, three members going by train to the summit of the Brienz Rothhorn, the others remaining at the lower level; both groups performed given amounts of muscular exercise and conducted similar physiological investigations. Finally the groups changed places, and the work was continued as before. This formed the first part of the inquiry; the second part was of a more severe character. Starting from that delightful valley in which Gressoney-la-Trinité nestles among the flowery slopes of the Lysthal, the party ascended to the Col d'Olen, where, at a height of 9,420 feet, Mosso has established his lower mountain laboratory. After spending some days in preparations, four members of the party and Prof. Sella, of Rome, climbed with guides and porters to the summit of the Signal Kuppe or Point Gnifetti of Monte Rosa, 14,965 feet. Here they stayed for seven days in the hut, now widely known as the Capanna Osservatorio Regina Margherita, which was erected for experimental purposes through Mosso's endeavors. The first days were most tempestuous, and the account of the stay on the summit is full of interest; an incident in the week was the recovery of a collapsed Alpine tourist, who, to the surprise of the party, turned out to be a lady. The whole party suffered more or less severely from mountain sickness, and a valuable part of the investigations deals with this familiar complaint.

Animals were taken up all the ascents for experimental purposes, others being left below for control observations.

The physiological results are related respectively to the influence of moderate altitudes, i. e., up to 7,500 feet, and of high altitudes up to nearly 15,000 feet, the former being chiefly the Brienz-Rothhorn experiments, the latter the Monte Rosa ones. They may be briefly summarized under the following different headings:

(1) *Blood Changes.*—It is now well known that, as first suggested by Paul Bert, the blood is altered in high altitudes. The most striking change is that discovered by Viault, who found that the red blood corpuscles increased from five millions to seven or eight millions per cubic millimeter of blood. Similar increase was observed in the present expedition, but it was somewhat uncertain in character. The determination of the specific gravity of the blood and of the serum showed that the increase when present was not due to plasma diminution through the excessive evaporation of perspiration; moreover, an examination in animals of the tissue which is the seat of the corpuscular formation (the red marrow of the bones) showed that this was in a state of greatly augmented activity. There is therefore no question that the red corpuscles increase in number, and the authors state in their work that the stimulating influence is the diminished oxygen tension of the blood itself.

(2) *Digestive Efficiency.*—By careful quantitative examinations of the food and excreta, it was shown that altitudes up to 8,000 feet exercised a favorable influence upon the completeness of the digestive processes, the indigestible residues diminishing especially when the surroundings were cold. In very hot surroundings this favorable influence was not so apparent, and in these circumstances muscular exertion caused it to be of the reverse type. At very high altitudes, 14,900 feet, the efficiency of digestion was greatly impaired.

(3) *Oxidation Processes.*—The extent of these was determined by the relation between the absorbed oxygen and the total heat production of the body. It appeared that even at such low altitudes as 1,500 feet the total oxidation was increased, this being exceptionally high during muscular exertion, while in moderate and high altitudes the oxidation processes were greatly increased. The increase is set down to two circumstances—firstly, the diminished thermogenetic capacity of the muscles, which are impaired by the inadequate supply of oxygen in their circulating blood, thus throwing the necessary heat production upon the oxidation of more complex compounds than those offered by the muscles; secondly, the presence in the tissues of abnormal oxidizable substances.

(4) *Proteid Metabolism.*—The most important of the numerous changes brought forward in the results of the expedition are those connected with the fundamental nitrogenous substances, proteids. It has been firmly established in physiology that while every growing animal assimilates through food more nitrogen than is excreted, this is not the case in the adult except in special circumstances. Growth implies proteid storage, which is believed to be utilized for the increased formation of cellular structures, and even in the adult such local muscular growth may occur as the result of special muscular exercise, training, etc., but it soon reaches a limit and is comparatively insignificant. In the convalescent it is a marked feature of recovery from wasting illness. After making due allowance for all disturbing influences, a most important result was arrived at by the work of the expedition. Even at Brienz (1,500 feet) a stage was reached in which the total N-import exceeded the N-export, while on the Rothhorn this excess was most marked. Moreover, this phase of metabolism persisted for a considerable time after leaving the moderately high altitude. This implies the production of a phase of nitrogenous metabolism resembling that of the growing animal; it is, in short, a renewal of youth. It is noteworthy that along with this nitrogen storage there was no corresponding increase of body weight, the intensity of the oxidation processes in non-nitrogenous compounds being more than sufficient to mask the proteid gain. At the highest altitudes the gain was not so apparent, but this is amply accounted for by the digestive derangement which was associated with the mountain sickness.

(5) *Respiration and Circulation.*—The decrease of the oxygen tension in the blood in consequence of the decreased partial pressure of the oxygen of the air was in accordance with the results obtained by Hüfner and others in connection with hæmoglobin. In opposition to Mosso's results the authors found that there was not a decreased tension of carbonic acid in the blood. They bring forward evidence which suggests that deficiency of oxygen in the blood can, like excess of carbonic acid, stimulate the respiratory center; this is of interest as it is opposed to the physiological view now generally accepted. The peculiar type of breathing known as the Cheyne-Stokes respiration, described by Mosso as occurring at high altitudes, was observed by the members of the expedition on Monte Rosa, but the explanation now advanced is quite different from that offered by Mosso. Zuntz regards the phenomenon as impaired activity of the respiratory centers, which are only capable of being adequately roused if the carbonic acid has by accumulation reached a certain tension in the blood.

As regards the circulatory changes, the only one of a fundamental character appeared to be due to the altered activity of the heart. At moderate altitudes the heart's activity, like that of the respiratory mechanism, is augmented to meet the need for more oxygen and more effective oxygen transport by the blood, but at very high altitudes there appeared to be a great tendency to cardiac weakness owing to the direct action of insufficient oxygen in the blood supplying the muscular walls of the heart.

This scanty and imperfect sketch may serve to show the very extensive field which is covered by the physiological work of the expedition, but, in addition, many valuable observations were made upon the symptoms, progress, and nature of mountain sickness. The cause of this complaint is, according to the authors, the deficiency of oxygen transport by the blood. The individual variations in the manifestation of the symptoms and the disappearance of the symptoms on habituation are considered to be due to the relative adequacy or inadequacy of the mechanisms by which the organism endeavors to protect itself against this oxygen deficiency. One such mechanism is the circulation flow, and if this is unable to bear the strain of increase, then nervous influences diminish the vascular area of the digestive organs in order to supply, so far as practicable, the higher nerve centers in the brain; in consequence of this anæmia, an extensive derangement of the digestive functions is produced which shows itself in the sickness and other symptoms that are the characteristic features of the trouble.

In conclusion, attention must be directed once again to the practical bearing of the Rothhorn experiments. These deal with the effects produced by moderately high altitudes, and to such altitudes thousands of men and women go every year, while the numerous sanatoria frequented by invalids are situated at these elevations. Moderate altitudes of less than 8,000 feet appear, in consequence of the lessened atmospheric pressure, to benefit the whole organism in the following particulars: The tissue which produces the oxygen carriers of the blood is stimulated into greater activity, the oxidation of abnormal substances is increased, the heart's action is augmented, the respiratory muscular mechanism is brought into more energetic use, and, finally, that proteid assimilation which is so directly related to cell growth and cell restoration assumes the phase present in the young and growing animal. In consequence of all these changes, and

* Höhenklima und Bergwanderungen in ihrer Wirkung auf den Menschen. By N. Zuntz, A. Loewy, F. Müller, and W. Caspari. Pp. xvi. + 494, and tables. Dedicated to E. Pflüger, in celebration of the jubilee of his doctorate. (Berlin, Bong & Co., 1906.)

particularly the last one, altitudes of from 4,000 to 7,000 feet must exercise a most beneficial and even rejuvenating influence. In the case of many invalids the effect will be to arm the body for its fight against such insidious foes as the tubercle bacillus and to hasten recovery in all cases of convalescence from bodily or mental prostration. Only those whose circulation is seriously impaired directly or indirectly by organic disease are debarred from the probability of such beneficial effects.

Experience has revealed to many the profound truth

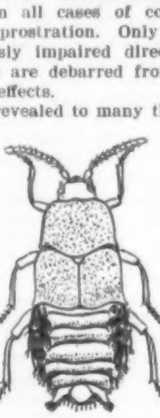


FIG. 1.—ATEMELES PUBLICOLLIS, A TROUBLESOME GUEST OF THE ANTS (MAGNIFIED).

which is expressed in the beautiful and familiar words, "I will lift up mine eyes unto the hills, from whence cometh my help." In their monumental work Prof. Zuntz and his colleagues present physiological reasons for the assurance that while mountain scenery may arouse the imagination, mountain air will stimulate those organic functions which form the foundation for health of body and happiness of mind.—Nature.

THE WAYS OF THE ANT.*

ONE of the most interesting phenomena of ant life is the symbiosis, or living together, of different species of ants, and of ants with other insects.

FIG. 2.—ATEMELES RIDING ON ONE ANT AND FED BY ANOTHER.

In the latter case, which corresponds to Wasmann's individual symbiosis, the relations between the ants and the alien insects vary greatly. For example, many ants keep aphides or other insects as "cows" and use their saccharine excretions as food. Other guests,, tended as carefully, "pay their board" with secretions which appear to be valued by the ants as stimulants rather than as food. Then there are dwellers in the ant hill that are merely tolerated and not fed by their hosts, and other intruders that prey upon the young brood and live in constant warfare with the ants, and, lastly, there are true parasites.

Wasmann's social symbiosis exists between ants of different species and includes connected colonies, whose relations may be hostile, friendly, indifferent, or those of guardian and ward, and mixed colonies,

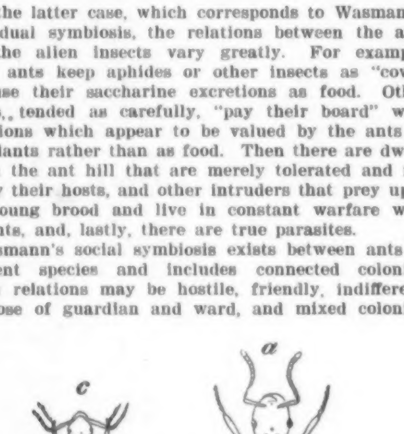


FIG. 3.—a, SLAVE-HOLDING POLYERGUS. c, SLAVE, FORMICA FUSCA.

which usually invove either slavery or social parasitism. A very peculiar case of individual symbiosis is observed in the fostering care given by certain ants to the beetles *Lomechusa* and *Atemeles* (Figs. 1 and 2) although these attack the young brood and endanger the life of the colony. The ants have been seen dragging these troublesome guests from impending danger and feeding them and their larvæ, and they often lick certain parts of the beetles' bodies which excrete the agreeable stimulants above referred to. In these and other beetles that live as cherished guests in ant hills the mouth and palpi are ill adapted to unaided feed-

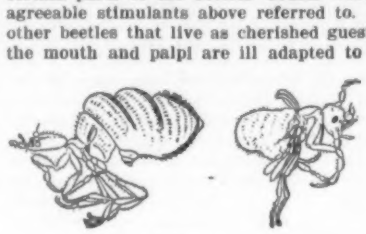


FIG. 4.

FIG. 5.

FIG. 4.—GUESTS OF THE TERMITOXENIA (MAGNIFIED). FIG. 5.—DINARDA OF WHICH THE SPECIES ARE INCIPIENT.

ing and the antennæ and forelegs, which have undergone appropriate modifications, are used as clubs with which to beat their hosts as a gentle reminder that food is desired. The beetles are furnished with tufts of hair from which the volatile secretions exude, and with long bristles which, when touched by the ants, stimulate the secreting organs.

In one variety of social symbiosis, which has been studied by Forel in South America, and by Wheeler in Mexico, the galleries of the two ant hills communi-

FIG. 7.—PAPER NEST OF BRAZILIAN ANT.

cate but the fusion of the colonies is incomplete. In other cases a colony of small ants makes its abode within the hill of a larger species, forming narrow passages which open into the larger ones of its hosts, with which its relations may be hostile, indifferent or friendly. In the last case the little ants are not merely lodgers. They are fed by their big cousins, upon whose backs they mount, and beg for food by licking their bearers.

More intimately united than any of these connected

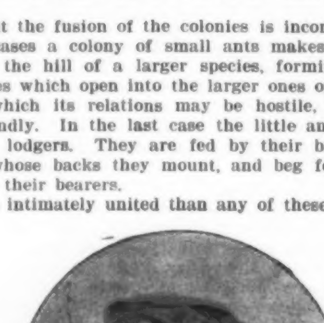


FIG. 6.—NEST OF LEAVES SEWN TOGETHER BY LARVÆ.

colonies are the mixed colonies of the slaveholding ants, which include the European red ants *Polyergus rufescens* (Fig. 3), and *Formica sanguinea* and an American sub-species of each. The blood-red ants, both European and American (*F. sanguinea*) keep few slaves and are not entirely dependent upon them, for colonies without slaves are met with, but *Polyergus rufescens* cannot exist without its slaves. The slaves are worker ants, usually captured from the nests of some particular species. Mixed colonies containing three species of ants are also found. In a curious case observed by Wasmann during two years, a colony of *F. sanguinea* existed normally with captive workers of *F. fusca* until it was compelled by the want of a queen to adopt a young queen of *F. pratensis*, after which adoption the colony contained ants of three species until the beginning of winter. *F. sanguinea*, which changes its abode according to the season, then withdrew, but returned to the hill in the following spring.

Besides such adoptive colonies originating through loss of queens, and ordinary slaveholding colonies with

FIG. 8.—PAPER NEST OF AFRICAN ANT, WITH TWO INCLOSURES FOR BARK LICE.

workers of another species, there are mixed colonies which contain not only workers, but also perfect females and males of two species. The mixed colonies of *Anergates* and *Tetramorium* are very peculiar. The former has no workers, its males are wingless and otherwise degenerated and its females are conspicuous for the great size of the abdomen. The mixed colony is formed by a queenless colony of *Tetramorium* adopting a pregnant queen of *Anergates*.

Haviland and Brauns have found small fat wingless flies (Fig. 4) living as guests with South African termites. They are not fed by their hosts but feed on the larvæ of the latter, yet they appear to be true guests, and not mere parasites. They have peculiar pectoral appendages which probably secrete a fluid agreeable to the termites and also serve as convenient handles in transportation.

Flies are also found living as guests of ants. From Wheeler's observations of one of these singular associations we learn that the larva of the fly adheres, by means of a sucking disk at its hinder end, to the larva of the ant, with which it shares the food, consisting of hashed insects, that the workers lay on the belly of the ant-larva—which always lies on its back. The ant-larvæ that are robbed in this way, however, develop as well as their unrobbed sisters. The parasite remains with its host during the pupal stage, the two pupæ being found together in the cocoon spun by the ant larva.

Escherich has discovered that the *Oxysoma* beetle, another guest of the ants, instead of being licked by its hosts, licks them greedily and lives on their exudations, thus costing them nothing for its food and also keeping them clean.

Certain guests of the ant-hill, belonging to the fam-

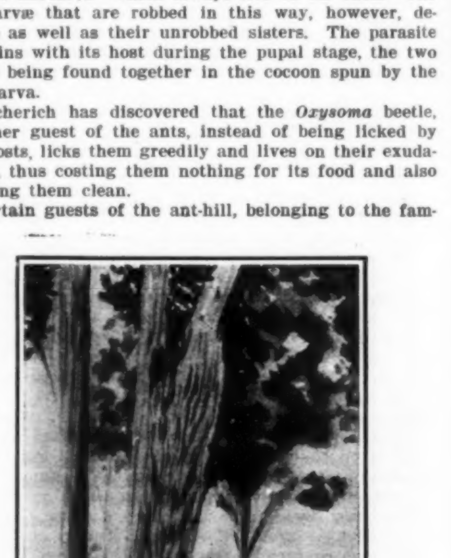


FIG. 9.—NEST OF AZTECA.

1/5 of natural size.

ily of mites, which were discovered by Haller more than twenty-five years ago, and which have recently been thoroughly studied by Wasmann, are literally "strongly attached" to their hosts. They ride on the backs of the ants or hang from their heads and demand food by beating them.

The development of species may be studied in some guests of the ants. Wasmann regards the varieties of *Dinarda* (Fig. 5) observed in European anthills as

* Adapted from the German of Dr. Friedrich Knauer, in Die Umschau.

incipient species, for a different variety is found in the hills of each species of ant.

Thirty years ago Forel discovered ant-types in addition to the normal males, queens and workers. Wasmann has studied these intermediate forms and distinguishes worker-like females which are able to replace queens, queen-like workers with well developed ovaries, gigantic workers resembling the so-called "soldiers" of some species, dwarf winged perfect females, and aborted forms fit for neither queens nor workers. He ascribes the origin of these cripples to unsuccessful attempts at transforming queen-larvæ into worker-larvæ to meet a scarcity of the latter caused by the ravages of beetles.

FIG. 10.—NEST OF AZTECA.

In a Texas species which normally includes males, queens, workers and soldiers, Wheeler has found individual workers of eight times the usual size. This great increase in bulk is caused by a parasitic worm, an inch long when uncoiled, which distends the abdomen directly and also induces ravenous appetite and consequent abnormal growth, as tape-worm sometimes does in the human subject.

Miss M. Holliday has found ten varieties of workers of a small ant that lives as the guest of a larger species. All of these forms have well developed ovaries and all but two have seminal reservoirs. Workers, therefore, cannot be summarily described as sterile females with atrophied ovaries but there is a gradual transition from the perfect female, or queen, through many intermediate forms, to the typical worker. Egg-laying workers are found in many species.

Linthicum described, long ago, an American ant that not only destroyed all vegetation around its hills except the *Aristida* grass, but actually *sowed* the latter. According to Wheeler, however, the *Aristida* grass about a hill is often insufficient for the support of a large colony and many hills are found remote from vegetation of any sort. These colonies are compelled to subsist on seeds brought from a distance and stored in the hills. The destruction or absence of vegetation about the hill keeps the storehouse dry by admitting the sun's rays to the surface and thus prevents, or lessens, waste through sprouting. Such seeds as do sprout are thrown out and to them is due the observed sparse growth of *Aristida* grass around the hill. A nearly related species, discovered by Wheeler in Texas, appears to mark the transition from vegetarian to carnivorous ants; for, though the workers live on stored grain, they hashed and fed to the larvæ flies that were given to them.

FIG. 11.—HANGING GARDENS OF THE ANTS.

Some species of ants convert certain of their workers into living honey pots by stuffing them with honey until their abdomens become as large as grapes, and a Brazilian termite appears to make a similar use of its "guest," a beetle (Fig. 4).

FIG. 13.—NUCLEUS OF MUSHROOM BED.

Holland described an East Indian ant (*Oecophylla*) that lives on trees, makes its nest of leaves fastened together by their edges and uses its larvæ as living shuttles by passing them over the edges of the leaves (held almost in contact by other workers) until the leaves are joined by a felted tissue of interlacing silken threads. This description has been verified by Prof. Chun, of the last German South Sea expedition, who finds that these larvæ possess spinning organs far more developed than those of any other hymenopterous insect. These ants, with the assistance of their larvæ, also weave around the trunk of the tree which bears the nest a foot-wide web as a protection against the incursions of a smaller and hostile species. This curious observation disposes of the human claim to priority in the invention of this device. A South American species, *Camponotus senex* (Fig. 6) also makes its nests of leaves sewn together by its larvæ and Goeldi has observed and studied the operation in the botanical gardens in Para.

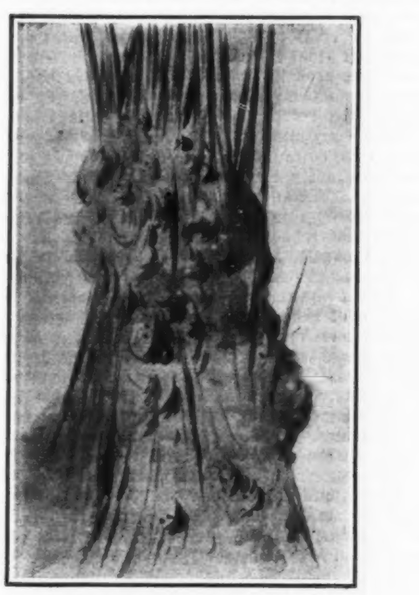


FIG 12.—ANTS' MUSHROOM BED.

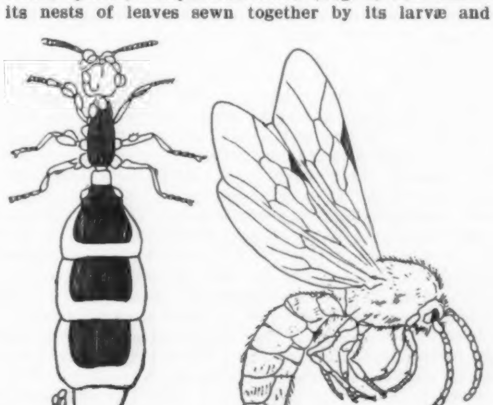


FIG. 14.—QUEEN AND WINGED MALE OF MIGRATORY ANTS. (AFTER WHEELER.)

Many tropical species of ants live on or in trees and, like wasps, construct very elaborate nests of paper, some of which are six feet in length. The nest shown in Fig. 7 is built in lofty tree tops in regions subject to inundations by a South American species which, in other districts, inhabits excavations made in decaying trees. Fig. 8 shows the paper nest of a South American ant. The protruding twigs bear galls made by a bark louse, which the ants have covered with clay to preserve their juices, of which they are very fond.

The arboreal genus *Azteca* (Figs. 9 and 10) of tropical America is remarkable for the variety of its habitations which, according to Forel, include ordinary suspended paper nests, excavations in decaying trunks and branches, nests formed under the bark or leaves of *lianes* and completed by paper walls abutting against the tree trunk, winding tubes of paper, paper nests built in hollow trees and "hanging gardens."

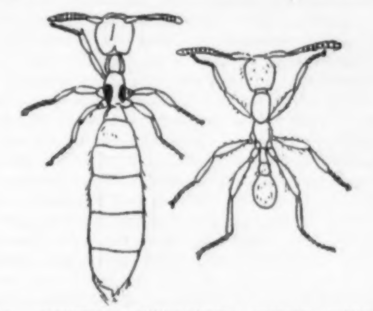


FIG. 15.—QUEEN COMPARED WITH WORKER OF MIGRATORY ANTS. (AFTER WHEELER.)

These hanging gardens involve a curious symbiosis of ants with plants, for certain Brazilian epiphytes, according to Ule, are found only on ants' nests and hence appear to be dependent upon the ants for their existence. After a rain, the large and cunningly constructed globular nest, of sponge-like texture, becomes covered with sprouting plants. The most luxuriant growth is found on the nest of a large black ant (Fig. 11) which often bears leaves (of Bromeliaceæ) ten feet in length. The improbability that ants would happen to build wherever the seeds of these plants chance to fall suggests that the ants are the sowers and cultivators, and the ants have actually been observed in the act of covering the seeds with earth. The plants repay the ants for their indispensable care by protecting them from the fierce sun and violent storms of the tropics. These hanging gardens of the ants form a striking feature of the landscape of the Amazon valley, where their brownish purple foliage is very conspicuous, especially on dead trees, on which they long continue to flourish.

FIG. 16.—POLARIZED FOOTPRINTS.

FIG. 17A.

FIG. 17B.

FIG. 17C.

FIG. 17D.

FIG. 17E.

FIG. 17.—BEETLE GUESTS OF ANTS, WITH (A, B, C, D, E) CURIOUSLY MODIFIED ANTENNÆ.

The horticulture of the ants is further illustrated by the fungus gardens or mushroom beds (Fig. 12) of the American genus *Atta*, which have been studied minutely by Forel and Von Thering and, more recently, by Goeldi and Huber. When the queen is ready to lay she sinks a narrow vertical shaft in the earth to a depth of about a foot and at the bottom of it excavates a lateral chamber. Then she closes the shaft

near its mouth. If the nest is opened a few days later the queen is found with a heap of twenty or thirty eggs in which segmentation has already commenced and another little heap of soft white matter, which is the nucleus of the garden (Fig. 13). This she has started by carrying in the back part of her mouth, from the mother colony, a pill made of fungus mycelium mixed with leaves and other matter. The garden grows rapidly and soon the transparent pear-shaped fungi known as "Moeller's kohlrabis" make their appearance. The soil and the first nutriment of the mushroom bed consists of some of the queen's own eggs. Goeldi has even caught this unnatural mother in the act of crushing her eggs for this purpose. She also eats many of them—subsists entirely on them, indeed—so that comparatively few are left to hatch. When the first workers have grown to maturity they open the shaft and the regular work of the colony begins. The largest workers bring in leaves, smaller ones cut them up, and the smallest sow the fragments and form additional mushroom beds.

The *Dorylinæ* or migratory ants (Figs. 14 and 15) of America and Africa are very peculiar, both biologically and morphologically, and are evidently primitive forms. Only within recent years have they been carefully studied, and the males and perfect females of a few species identified. The large winged insects that accompany the migrating troops look so little like ants, or each other, that the male and the female of the same species were often described under different specific and generic names, and even assigned to other orders of insects. No less than eight of these supposed species have been found to be males of one species of migratory ant. A few years ago no perfect females were known. The workers, also, vary greatly in size and form within a single troop.

Miss Adèle Fielde has investigated the tenacity of life in ants. She finds that they thrive best at a temperature of from 24 to 27 deg. C. (75 to 81 deg. F.). Below 15 deg. C. (59 deg. F.) they are very sluggish and they become motionless and apparently lifeless at the freezing point of water, although they are not killed by twenty-four hours' exposure to a temperature of —5 deg. C. (23 deg. F.). Heating to 50 deg. C. (122 deg. F.) is fatal. Ants survive immersion in water for two or three days.*

Miss Fielde has also studied the olfactory functions of the several joints of the antennæ and discovered that one joint detects the odor of the path, another the general odor of the colony, a third the odor peculiar to offspring of the same mother, etc. The removal of a certain number of joints completely destroys the nursing instinct and a further shortening of the antennæ enables ants of different species to live together in peace.†

The same observer has studied the reaction of ants to light and sound, or rather to vibrations. She found that ants in artificial nests, or formicaries, covered with blue and violet glass constantly strove to escape from the light, as did those that were under white glass. Ants covered with orange-yellow glass, on the other hand, behaved as if they were in darkness. This experiment proves that ants are sensitive only to the shorter waves.

Aerial sound waves had no effect on ants but the insects were very sensitive to vibrations conveyed by solid conductors to the base of the formicary.

According to Bethe, an ant makes a track in which the homeward is distinguished, in some mysterious way, from the outgoing direction. If a sharply defined path is blocked by interposing an obstacle, around which a new path must be made, outgoing and homecoming ants, imprisoned before the catastrophe and afterward set free on the new path which they had no share in making, hesitate only an instant and then set off in their proper respective directions. It is as if a man always wore shoes with ribbed soles on leaving home and shoes with checked soles on returning (Fig. 16). A friend, aware of this habit, meeting the trail at any point, would know which way to turn in order to reach the man's house. In the case of the ants this "polarization" of the track is probably chemical.

GEOLOGICAL TIME.‡

By Warren Upham.

The astronomer and the geologist ask, but cannot decisively answer, the question considered in this paper, "How old is the earth?" It is surely known to be very old, as compared with the span of human history; but the wide range of the most expert estimates and theories leaves it undetermined whether the measure of geological time is less than a hundred million years, or may be five to ten or twenty times longer. Investigations will be continued, we may hope, until a more satisfactory and convincing answer to this question shall be ascertained, with such fullness of evidence that it must receive general approval and acceptance.

Numerous eminent writers who have considered this subject from the standpoint of physical experiment and theory and their relationship with astronomy, including Lord Kelvin, Tait, Newcomb, Young, and Ball, tell us that geologists can be allowed probably no more than one hundred millions of years, and perhaps only about ten millions, since our earth was so cooled as to permit the beginning of life upon it. The series of geologic eras, so far as they are known from fossil faunas and floras, is only a part, perhaps a half or a third, or less, of the earth's age as a separate planet.

According to the nebular theory of Laplace, the physicist and astronomer, looking beyond the beginning of geology, see our solar system in the process of slow but very grand evolution, from a globular nebulous mass with as great circumference as the orbit of the outermost planet whose mass became first detached from the revolving nebula, followed successively by the inner planets to Mars, the earth, Venus, and Mercury, till finally the chief residual part of the nebula became the splendidly luminous sun. In like manner, as the planets became condensed to their present forms, most of them suffered a like severance of comparatively small portions of their masses to form moons and for Saturn both moons and rings. From measurements of the rate of radiation of the sun's heat, from the rate of downward increase of the earth's heat observed in deep mines and borings, and from experiments in the laboratory, aided by elaborate mathematical calculations, the physicist determines, to his own satisfaction, how long the sun can have been the center of light and life for his attendant planets, how long time has passed since the moon's mass was thrown off from our whirling world, then revolving more rapidly than to-day, and the duration of the ages since the once molten earth became incrusted and so far cooled that its ocean ceased to boil and vegetation and animal life began.

In researches based on premises of that nebular theory, Sir William Thomson (now Lord Kelvin) long ago estimated, from his study of the earth's internal heat, its increase from the surface downward, and the rate of its loss by radiation into space, that the time since the consolidation of the surface of the globe has been somewhere between 20 millions and 400 millions of years, and that most probably this time and all the geologic record must be limited within 100,000,000 years. Prof. George H. Darwin computes, from the influence of tidal friction in retarding the earth's rotation, that probably only 57,000,000 years have elapsed since the moon's mass was shed from the revolving earth, long before the formation of its crust. From the same arguments and the rate at which the sun is losing its store of heat, Prof. Guthrie Tait affirms that apparently 10,000,000 years are as much as physical science can allow to the geologist. Prof. Newcomb, summing up the results of these physical and astronomic researches, writes: "If the sun had, in the beginning, filled all space, the amount of heat generated by his contraction to his present volume would have been sufficient to last 18,000,000 years at his present rate of radiation . . . 10,000,000 years . . . is, therefore, near the extreme limit of time that we can suppose water to have existed on the earth in the fluid state." Not only the earth, but even the whole solar system, according to Newcomb, "must have had a beginning within a certain number of years which we cannot yet calculate with certainty, but which cannot much exceed 20,000,000, and it must end."

The geologist demurs against these latter far too meager allotments of time for the wonderful, diversified, and surely vastly long history which he has patiently made out in his perusal of the volume of science disclosed by the rocks. He can apparently do very well with Lord Kelvin's original estimate, but must respectfully dissent from the less liberal opinions noted. Somewhere in the assumed premises which yield to mathematicians these narrow limits of time, there must be conditions which do not accord with the actual origin and constitution of the sun and earth. It must be gratefully acknowledged, however, in the camp of the geologists, that we owe to these researches a beneficial check against the notion once prevalent that geologic time extends back practically without limit; and it is most becoming for us carefully to inquire how closely the apparently conflicting testimonies of geology and of physics may be brought into harmony by revision of each.

Among all the means afforded by geology for direct estimates of the earth's duration, doubtless the most reliable is through comparing the present measured rate of denudation of continental areas with the aggregate of the greatest determined thickness of the strata referable to the successive time divisions. Now the rates at which rivers are lowering the altitudes of their basins by the transportation of sediments to the sea vary from an average of one foot taken from the land surface of its hydrographic basin by the River Po in 730 years to one foot by the Danube in 6,800 years. As a mean for all the rivers of the world, Alfred Russel Wallace assumes that the erosion of all the land surface is one foot in 3,000 years. The sediments are laid down in the sea on an average within 30 miles from the coast, and the coast lines of the earth have a total measured length, according to Dr. James Croll and Mr. Wallace, of about 100,000 miles, so that the deposition is almost wholly confined to an area of about 3,000,000 square miles. This area is one-nineteenth as large as the earth's total land area; hence it will receive sediment nineteen times as fast as the land is denuded, or at the rate of about nineteen feet of stratified beds in 3,000 years, which would give one foot in 158 years. With this Wallace compares the total maxima of all the sedimentary rocks of the series of geologic epochs, measured in whatever part of the earth they are found to have their greatest development. Prof. Samuel Haughton estimates their aggregate to be 177,200 feet, which multiplied by 158 gives approximately 28,000,000 years as the time required for the deposition of the rock strata in the various districts where they are thickest and have most fully escaped erosion and redeposition.

It is comparatively easy to determine the ratios or relative lengths of the successive geologic areas, but confessedly very difficult to decide beyond doubt even the approximate length in years of any part of the records of the rock strata. The portions for which we have the best means of learning their lengths are the Glacial and Recent periods, the latter extending from the Champlain epoch or closing stage of the ice age to the present time, while these two divisions, the Glacial or Pleistocene period and the Recent, make up the Quaternary era. If we can only ascertain somewhat nearly what has been the duration of the era, from the oncoming of the Ice age until now, it will serve as a known quantity to be used as the multiplier for giving us the approximate or probable measures in years for the recedingly earlier and far longer Tertiary, Mesozoic or Secondary, Paleozoic or Primary, and Archean or Beginning eras, which last takes us back almost or quite to the time when the cooling molten earth became first enveloped with a solid crust.

The ratios reached by Profs. J. D. Dana and Alexander Winchell from the thicknesses of the rock strata are closely harmonious, the durations of Paleozoic, Mesozoic, and Cenozoic time being to each other as 12:3:1. The Tertiary and Quaternary ages, the latter extending to the present day, which are here united as the Cenozoic era, Dana would rank approximately in the ratio of 3:1, giving to the Quaternary a sixty-fourth part of all time since the beginning of the Cambrian period, to which our earliest well preserved fossil faunas belong. His estimate of the relative length of Quaternary time seems to me greatly exaggerated; but this would not sensibly affect the general ratios. Dana further ventured a supposition that these vast eras from the Cambrian down until now, may comprise some 48,000,000 years, which would give for the Paleozoic era, 36,000,000 years; the Mesozoic, 9,000,000; and the Cenozoic, 3,000,000. He disclaimed, however, any assumption that these figures are "even an approximate estimate of the real length of the interval, but only of relative lengths, and especially to make apparent the fact that these intervals were *very long*."

Prof. W. M. Davis, without speaking definitely of the lapse of time by years, endeavors to give some conception of what these and like estimates of geologic ratios really mean, through a translation of them into terms of a linear scale. Starting with the representation of the Postglacial or Recent period, since the North American ice-sheet was melted away, as two inches, he estimates that the beginning of the Tertiary erosion of the Hudson River gorge through the Highlands would be expressed by a distance of ten feet; that the Triassic reptilian tracks in the sandstone of the Connecticut Valley would be probably 50 feet distant; that the formation of the coal beds of Pennsylvania would be 80 or 100 feet back from the present time; and that the Middle Cambrian trilobites of Braintree, Mass., would be 200, 300, or 400 feet from us.

Having such somewhat definite and agreeing ratios, derived from various data by different investigators, can we secure the factor by which they should be multiplied to yield the approximate duration of geologic epochs, periods and eras, in years? If on the scale used by Prof. Davis we could substitute a certain time for the period since the departure of the ice-sheet, we would thereby at once determine, albeit with some vagueness and acknowledged latitude for probable error, how much time has passed since the Triassic tracks were made, the coal deposited, and the trilobites entombed in the Cambrian slates. Now just this latest and present division of the geologic record, following the Ice age, is the only one for which geologists find sufficient data to permit direct measurements or estimates of its duration. "The glacial invasion from which New England and other northern countries have lately escaped," remarks Davis, "was prehistoric, and yet it should not be regarded as ancient."

In various localities we are able to measure the present rate of erosion of gorges below waterfalls, and the length of the post-glacial gorge divided by the rate of recession of the falls gives approximately the time since the Ice age. Such measurements of the gorge and Falls of St. Anthony by Prof. N. H. Winchell show the length of the Postglacial or Recent period to have been about 8,000 years; and from the surveys of Niagara Falls, Prof. G. F. Wright and the present writer believe it to have been 7,000 years, more or less. From the rates of wave-cutting along the side of Lake Michigan and the consequent accumulation of sand around the south end of the lake, Dr. E. Andrews estimates that the land there became uncovered from its ice-sheet not more than 7,500 years ago. Prof. Wright obtains a similar result from the rate of filling of kettle-holes among the gravel knolls and ridges called kames and eskers, and likewise from the erosion of valleys by streams tributary to Lake Erie; and Prof. B. K. Emerson, from the rate of deposition of modified drift in the Connecticut Valley at Northampton, Mass., thinks that the time since the Glacial period cannot exceed 10,000 years. An equally small estimate is also indicated by the studies of Gilbert and Russell for the time since the highest rise of the Quaternary lakes Bonneville and Lahontan, lying in Utah and Nevada, within the arid Great Basin of interior drainage, which are believed to have been contemporaneous with the great extension of ice-sheets upon the northern part of our continent.

Prof. James Geikie maintains that the use of paleolithic implements had ceased, and that early man in Europe made neolithic (polished) implements, before

* Tenacity of Life in Ants, by Adèle M. Fielde, Scientific American, November 4, 1905.

† The Sense of Smell in Ants, by Adèle M. Fielde, Scientific American Supplement, No. 1549, September 9, 1905.

‡ Popular Astronomy.

the recession of the ice-sheet from Scotland, Denmark, and the Scandinavian peninsula; and Prestwich suggests that the dawn of civilization in Egypt, China, and India, may have been coeval with the glaciation of northwestern Europe. In Wales and Yorkshire the amount of denudation of limestone rocks on which bowlders lie has been regarded by Mr. D. Mackintosh as proof that a period of not more than 6,000 years has elapsed since the bowlders were left in their positions. The vertical extent of this denudation, averaging about six inches, is nearly the same with that observed in the southwest part of the Province of Quebec by Sir William Logan and Dr. Robert Bell, where veins of quartz marked with glacial striæ stand out to various heights not exceeding one foot above the weathered surface of the inclosing limestone.

Another indication that the final melting of the ice-sheet upon British America was separated by only a very short interval, geologically speaking, from the present time, is seen in the wonderfully perfect preservation of the glacial striation and polishing on the surfaces of the more enduring rocks. Of their character in one noteworthy district, Dr. Bell writes as follows: "On Portland promontory on the east coast of Hudson's Bay, in latitude 58 deg. and southward, the high rocky hills are completely glaciated and bare. The striæ are as fresh-looking as if the ice had left them only yesterday. When the sun bursts upon these hills after they have been wet by the rain, they glitter and shine like the tinned roofs of the city of Montreal."

From this wide range of concurrent but independent testimonies, we may accept it as practically demonstrated that the ice-sheets disappeared from North America and Europe some 6,000 to 10,000 years ago. But having thus found the value of one term in our ratios of geologic time divisions, we may know them all approximately by its substitution. The two inches assumed to represent the postglacial portion of the Quaternary era may be called 8,000 years; then according to the proportional estimates by Davis, the Triassic period was probably 2,400,000 years ago; the time since the Carboniferous period, in the closing part of the Paleozoic era, has been about four or five millions of years; and since the middle of the Cambrian period, twice or perhaps four times as long. Continuing this series still farther back, the earliest Cambrian fossils may be 20 or 25 millions of years old, and the beginning of life on our earth was not improbably twice as long ago.

Seeking to substitute our measure of postglacial time in Dana's ratios, we are met by the difficulty of ascertaining first its proportion to the preceding Glacial period, and then the ratio which these two together bear to the Tertiary era. It would fill a very large volume to rehearse all the diverse opinions current among glacialists concerning the history of the Ice age, its wonderful climatic vicissitudes, and the upward and downward movements of the lands which are covered with the glacial drift. Many eminent glacialists, as James Geikie, Wahnschaffe, Penck, De Geer, Chamberlin, Salisbury, Leverett, Shaler, McGee, and others, believe that the Ice age was complex, having two, three, or more epochs of glaciation, divided by long interglacial epochs of mild and temperate climate when the ice-sheets were entirely or mainly melted away. The astronomic theory of Croll attributes the accumulation of ice-sheets to recurrent cycles which bring the earth alternately into aphelion and perihelion each 21,000 years during the periods of maximum eccentricity of the earth's orbit. Its last period of this kind was from about 240,000 to 80,000 years ago, allowing room for seven or eight such cycles and alternations of glacial and interglacial conditions. The supposed evidence of interglacial epochs therefore gave to this theory a wide credence; but the more recent determinations of the geologic brevity of time since the ice-sheets disappeared from North America and Europe make it clear, in the opinions of some of the geologists who believe in a series of Quaternary glacial epochs, that not astronomic but geographic causes produced the Ice age.

Glacialists who reject Croll's ingenious and brilliant theory mostly appeal to great preglacial altitude of land as the chief cause of the ice accumulation, through either its direct or indirect climatic results, citing as proof of such altitude the fjords and submarine valleys which on the shores of Scandinavia, and the Atlantic, Arctic, and the Pacific coasts of North America, descend from 1,000 to 3,000 and even 4,000 feet below the sea level, testifying of former uplifts of these continental areas so much above their present heights. But beneath the enormous weight of their ice-sheets these lands finally sank, so that when the ice in many parts of its extent attained its maximum area and thickness, and during its departure, the areas on which it lay were depressed somewhat lower than now and have since been re-elevated. This view to account for the observed records of the Glacial period has been held by Dana, LeConte, Wright, Jamieson, and others, including the present writer. It is believed to be consistent either with the doctrine of two or more glacial epochs during the Quaternary era, or with the reference of all the glacial drift to a single glacial epoch, which is thought by Wright, Prestwich, Lamplugh, Falsan, Holst, myself, and others, to be more probable. The duration of the Ice age, if there was only one epoch of glaciation, with moderate temporary retreats and readvances of the ice-border sufficient to allow stratified beds with the remains of animals and plants to be intercalated between accumulations of till, may only have comprised a few tens or scores of thousands of years.

From various estimates of the relative ages of different portions of the drift sheets, we have the probable length of Glacial and Postglacial time together 50,000 or 100,000 years, more or less; but a probably long preceding time, while the areas that became covered by ice were being uplifted to high altitudes, may perhaps with good reason be also included in the Quaternary era, which then would comprise some 150,000 years. Comparing the Tertiary era with the Quaternary, however, I cannot agree with Prof. Dana's estimate that the latter was a third as long as the former, and am quite at a loss to discern evidences justifying that view. The best means for learning their ratio I think are to be found in the changes of faunas and floras since the beginning of the Tertiary era, using especially the marine molluscan faunas as most valuable for this comparison. Scarcely any species of marine mollusks have become extinct or undergone important changes during the Glacial and Recent periods, but since the Eocene dawn of the Tertiary nearly all of these species have come into existence. Judged upon this basis, the Tertiary era seems at least thirty or forty times longer than the Ice age and subsequent time; in other words, it may well have lasted two millions or even four millions of years. Taking the mean of these numbers, or three million years, for Cenozoic time, or the Quaternary and Tertiary ages together, we have precisely the value of Prof. Dana's ratios which he himself assumed for conjectural illustration, namely, 48,000,000 years since the Cambrian period began. But the diversified types of animal life in the earliest Cambrian faunas surely imply a long antecedent time for their development, on the assumption that the Creator worked then as during the subsequent ages in the evolution of all living creatures. According to these ratios, therefore, the time needed for the deposition of the earth's stratified rocks and the unfolding of its plant and animal life must be about a hundred millions of years.

Reviewing the several results of our different geologic estimates and ratios supplied by Wallace, Haughton, Dana, the Winchells, Davis, and others, we are much impressed and convinced of their approximate truth by their somewhat good agreement among themselves, which seems as close as the nature of the problem would lead us to expect, and by their all coming within the limit of 100,000,000 years which Sir William Thomson estimated on physical grounds. This limit of probable geologic duration seems therefore fully worthy to take the place of the once almost unlimited assumptions of geologists and writers on the evolution of life, that the time at their disposal has been practically infinite.

The foregoing arguments, computations, and estimates, yielding about a hundred million years for the age of the earth so far as it is known through the observations of geology, seem to me mostly acceptable and true, although the more exact knowledge of astronomy, physics, and chemistry, attained during the past century, shows that the nebular theory formulated by Laplace needs great modifications, being partially superseded by the meteoritic hypothesis of Lockyer and Darwin and by the planetesimal theory of Chamberlin.

Instead of an originally gaseous and very hot condition of the parent nebula, as supposed by Laplace, it appears far more probable that the nebula in its earliest definable state consisted of meteorites, that is, particles and little masses of solid and cold matter. Sir Norman Lockyer, reasoning from his extensive investigations in spectrum analyses, presents this view as follows: "Nebulæ are really swarms of meteorites or meteoritic dust in the celestial spaces. The meteorites are sparse, and the collisions among them bring about a rise of temperature sufficient to render luminous some of their chief constituents."

Besides the testimony of the spectroscope concerning the characters of the nebulæ, we may consider the rings of Saturn, which are very thin but have great areal extent, as probably a strong evidence of the meteoritic derivation of the planets and the sun. Richard A. Proctor, after stating the physical impossibilities of the existence and permanence of these unique rings as either solid or liquid continuous bodies, wrote: "The sole hypothesis remains that the rings are composed of flights of disconnected satellites, so small and so closely packed that, at the immense distance to which Saturn is removed, they appear to form a continuous mass." In other words, the Saturnian rings are made up of myriads of separately-moving small masses, which are doubtless similar to the stony meteorites that fall rarely on the earth.

Again, the origin of the hundreds of asteroids, or minor planets, mostly no more than a few miles in diameter, but including several from 100 to perhaps about 300 miles in diameter, seems very readily explained under this modification of the nebular theory.

Prof. Young well says: "The *meteoric* theory of a nebula does not in the least invalidate, or even to any great extent modify, the reasoning of Laplace in respect to the development of suns and systems from a *gaseous* nebula. The old hypothesis has no quarrel with the new."

Another theory, which differs more widely from the Laplacean hypothesis, has been very recently proposed by Prof. T. C. Chamberlin, of the University of Chicago, who names it the Planetesimal Hypothesis. His studies in this direction have been in progress about five years, with publication of preliminary papers, preparing the way for the new hypothesis; but its first somewhat detailed statement in print appeared only about a year ago.* Since the beginning of the present year, this new theory has been very amply set forth in a geological text-book, with illustrative diagrams.* It is a more applicable nebular theory, especially having in view the origin of the earth; and it will certainly introduce into geology and geophysics many new and fruitful methods of observation and research. Indeed, nearly all the great fields of theoretical geology now require renewed investigation, by which the planetesimal hypothesis shall be tested.

Chamberlin, in this grand philosophic study, contributes greatly to the establishment of an acceptable nebular theory, consistent with the known relations of the planets, their satellites, and the sun, by his derivation of the solar system from a spiral nebula, and by his indicating the probable mode of origin of such nebulæ, which abound by tens of thousands throughout the starry heavens, as discovered by the most powerful telescopes.

Both the meteoritic and planetesimal hypotheses seem to me probably true in their regarding the nebulous matter from which planets and suns are made as having become mostly solid, though finely divided, and as very cold, being in almost absolutely cold and immensely extended space, previous to the condensation and aggregation which formed it into worlds and stars. During the accumulation of the planets and their satellites, much or perhaps nearly all the nebulous matter forming them had remained, until thus gathered as great bodies, apparently in solid and cold molecules or in small masses brought together by their gravitative attraction, as seems reliably evidenced by the rings of Saturn and by the many little asteroids.

Coming to the question whether the accumulation of so large a body as the earth by the infalling of small and large planetesimal bodies could take place without its becoming intensely hot and molten, somewhat like the sun, we have first the observations and theories of geology to aid in giving an answer, and these may be advantageously supplemented by the physiographic features of our satellite, the moon. It has been long held by geologists that the downward increase of heat in the earth's crust, present volcanoes, the widely-distributed evidences of ancient volcanic action, and thermal metamorphism of great rock formations, indicate an internal temperature which must fuse any known rocks, unless they are prevented from this by overlying pressure. The new hypothesis of Chamberlin accounts for vulcanism, and for all that we know of the earth's internal heat, fully as well as the Laplacean hypothesis of condensation of an intensely hot gaseous nebula, while it better accords with the physical and dynamic relations of the planets and sun.

When our inquiry is turned to the moon, we see a most wonderful record, as it is generally regarded, of extinct volcanic action, implying a formerly very hot and probably almost wholly molten state of that globe, which has a little more than one-fourth the diameter of the earth. Under the planetesimal hypothesis, these two companion globes were doubtless accumulated similarly. The moon, after acquiring its present size, had multitudes of volcanoes which left round craters, or parts of their crater rims, of varying dimensions from those at the limit of telescopic vision up to one with a diameter of about 800 miles, or nearly four-fifths of the moon's radius. So great a lake or sea of molten rock, similar to the calderas of Hawaiian volcanoes, but of vastly larger area, whose crater rim is partially preserved in the lunar Carpathian-Apennine-Caucasus chain of mountains, could only exist when much of the interior of the moon was melted. It seems possible and indeed probable, therefore, that the earth, whether formed as supposed by the old or the new nebular hypothesis, was nearly or quite all melted during a considerable part of the time of its accumulation. The planets undoubtedly tended in some degree toward the same intensely hot condition which is reached by the sun and stars in the concentration of originally nebulous matter.

If we accept the planetesimal theory of the formation of the earth and moon, we must suppose that nearly all the ingathering of the formerly scattered material had been accomplished before the deposition of the earth's Paleozoic sediments, else they would here and there reveal evidences of collision of some of the previously planetesimal masses. Geologic antiquity, as hitherto studied, falls far short of reaching back to the time of completion of the creation of these companion globes, the earth and its satellite, in nearly the same size and conditions which they have now. But in the new views opened by the planetesimal hypothesis the range of geologic inquiries and theories is extended almost inconceivably farther back, through the laying of "the foundation of the earth."

* "Fundamental Problems of Geology," in Year Book No. 3, for 1904, of the Carnegie Institution of Washington, published in January, 1905, pp. 195-258.

* Geology. By Thomas C. Chamberlin and Rollin D. Salisbury. In three volumes. (New York, Henry Holt & Co.) Vol. I, Geologic Processes and Their Results, 1904; pp. xix, 654. Vols. II. and III. Earth History, 1906; pp. xxvi, 692, and xi, 624. The Planetesimal Hypothesis is the chief theme of Chapter I, pp. 1-81, in Vol. II; and discussions of "The Hypothetical Stages leading up to the Known Eras," in Earth History, form Chapter II., pp. 82-122, in the same volume.

ORIGIN AND HISTORY OF GUN-COTTON.

THE first step in the discovery of gun-cotton was made by the French chemist, Braconnot. In 1832, he obtained, by the action of strong nitric acid on starch, a highly combustible product, which he called "Xyloidine." Pelouze, in 1838, observed that cotton, linen, paper, etc., treated with strong nitric acid, increased in weight, and became easily combustible. Little attention was paid to these substances till the year 1846, when the German chemist Schönbein announced the discovery of cotton powder, or gun-cotton, which might

be used as a substitute for gunpowder. Soon afterward Böttger and Otto independently discovered gun-cotton. The method of manufacture was not made public until 1847, when Knop, also Kamarsch and Heeren, prepared gun-cotton by means of a mixture of nitric and sulphuric acids. About the same time, Millon and Gaudin employed a mixture of sulphuric acid and nitrate of potash and soda, which they found to have the same effect. Gun-cotton at once became an object of great scientific and practical interest, and its manufacture was undertaken in England, France, and Russia. Unfortunately, several explosions occurred, which temporarily caused its manufacture to be entirely abandoned in this country and in France. In Austria, Gen. von Lenk still continued to carry out experiments, and succeeded in improving its manufacture to such an extent that in 1853 a factory was erected under his supervision at Hirtenberg, near Vienna. This factory was officially closed in 1865, owing to the explosion of two magazines. The success of Lenk's process, however, attracted the notice of English scientists, and formed the basis of Sir Frederick Abel's address at the annual meeting of the British Association at Newcastle, in 1863, with the result that Mr. Prentice, of Stowmarket, in collaboration with Sir F. Abel, erected a factory. Gun-cotton made according to Lenk's process was chiefly manufactured from long staple cotton in the form of yarn dipped in a mixture of nitric and sulphuric acids, and afterward put into cages or wire baskets, placed in a stream of running water, and allowed to remain several weeks, until sufficiently purified from free acids, so as to be comparatively stable. If required for mining purposes, the yarn was afterward twisted, and made into ropes of various sizes, chiefly from ½-inch to 1¼-inch diameter, according to the size of the bore hole in which it was to be used. It was afterward cut into lengths of from 4 inches to 5 inches, and dried, each length forming a charge for blasting purposes. During the next few years a large trade was done in the above form of charge, more particularly with the slate quarries in Wales. At the same time many experiments were carried out, with a view to taming gun-cotton sufficiently for use in shot guns, rifles, and cannon.

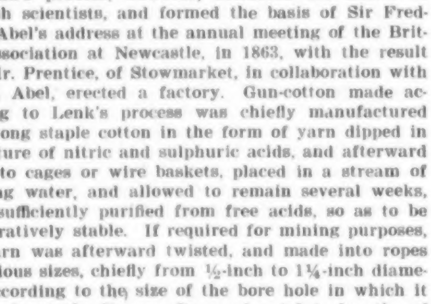


Fig. 1.—EXPANSION WITH EXTERNAL WORK AND LIQUEFACTION UNDER PRESSURE.

The form chiefly used was a braided tube like certain lamp wicks, or a braided rope or coil, similar to engine packing, the idea being that the sportsman having several yards in this form in his possession would cut off an inch or more and charge his gun or cartridge cases as occasion required.

For rifles, the gun-cotton yarn was sometimes tightly pressed into paper or wood tubes which were afterward covered with gun-cotton braid so as to occupy the same space in the chamber of the rifle as a charge of black gunpowder. Charges for cannon were also made upon the same principle, but the results in gun, rifle, and cannon were very erratic and unreliable. Sometimes the charge exploded with great violence. At other times it was scarcely powerful enough to send the shot out of the gun.

About the year 1865, the whole process of manufacture was revolutionized by Abel's patent, which, by a system of pulping and purifying, enabled the inventor to obtain a density and purity hitherto unattainable. It also enabled him to use a super white or comparatively cheap cotton waste instead of the expensive long staple cotton formerly employed.

THE COMMERCIAL PRODUCTION OF OXYGEN BY THE LIQUID AIR PROCESS.*

By Georges Claude.

The industrial importance of oxygen is increasing very rapidly. Its applications to projection, the lighting of automobiles, the manufacture of artificial rubies, and, most important of all, to the welding and cutting of sheet iron, are only the first stages of a development which is destined to do away with blast furnaces, revolutionize chemical industry, and profoundly modify methods of lighting.

I have contributed in some small degree to this evolution, which I advocated as long ago as 1897.

Recently a new agent, liquid air, has furnished me with the means, long sought, of obtaining oxygen easily and cheaply from the atmosphere.†

It has long been known that in the evaporation of liquid air most of the nitrogen passes off first, leaving a mixture richer in oxygen. Parkinson clearly pointed out in 1892 the possibility of separating the two gases by this method economically by recovering the energy expended in evaporation, but liquid air was so costly, so difficult to obtain, that this property remained unused until the production of oxygen in large quantities was made possible by the invention of Linde's apparatus.

In 1899 I began experimenting with a view to improving the process of making liquid air. Instead of seeking to reduce the temperature to a point at which air is liquefied by its mere escape from a pressure of 200 atmospheres (expansion without external work) I succeeded in effecting the expansion in compressed-air motors working at the temperature of liquid air (expansion with external work) though many experimenters declared this result impossible. In gasoline I found a lubricant which remains liquid even at this low temperature. By this method, with the aid of liquefaction under pressure (Fig. 1) and using pressures of only 30 or 40 atmospheres, I secured a much better effect than had been obtained with 200 atmospheres and expansion without external work.*

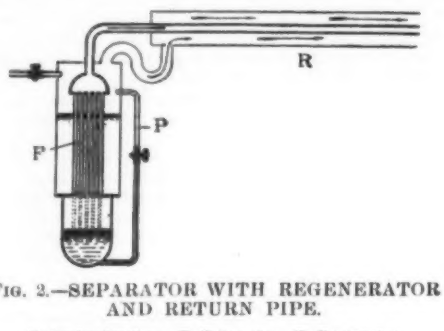


Fig. 2.—SEPARATOR WITH REGENERATOR AND RETURN PIPE.

F. Condensing pipes. P. Return pipe. R. Regenerator.

In the application of liquid air to the production of oxygen, also, I adopted a course opposed to that of my predecessors. An inexact experiment by Dewar had led to the belief that in the liquefaction of air its two components liquefy simultaneously. In accordance with this view, in order to utilize the absorption of heat by the evaporating liquid air, air at 3 or 4 atmospheres pressure was forced through pipes (*F*, Fig. 2) immersed in the liquid, the compressed air having been previously cooled by pressing through a small pipe surrounded by a larger one through which flowed the products of evaporation of the liquid air which bathed the pipes *F*. As the compressed air liquefied it caused the evaporation of an equal quantity of the surrounding liquid air. The gas thus evolved could be separated into two portions, respectively poor and rich in oxygen, and the regenerating pipes (Fig. 2, above) reduced the loss of energy to a minimum. But though the selective evaporation was utilized, the selective condensation was ignored. The compressed air was completely liquefied so that the resultant liquid, which was subjected in turn to selective evaporation in the next operation of the apparatus, contained only the normal proportion of oxygen, 21 per cent.

I have pointed out Dewar's error. The phenomena of condensation of air are, as logically they should be, the exact opposites of the phenomena of evaporation. As nitrogen is more volatile than oxygen, it is also less easily condensed. Consequently, when a mass of air is gradually liquefied, the portion of the liquid which first condenses is richest in oxygen. (I was anticipated in this correction, as I have since learned, by the Canadian physicist Lesueur.)

In order to utilize this property I added the return pipe connecting the two liquid air chambers (Fig. 2), which enables me to convert all of the oxygen and part of the nitrogen of the compressed air into a liquid containing 48 per cent of oxygen, leaving a gaseous residue of pure nitrogen, amounting to more than half the volume of the original air, which need not be liquefied.† This method of operation offers two great advantages: All the oxygen is secured by the condensation of a comparatively small quantity of liquid, the yield of oxygen per horse-power hour being thus increased by about 50 per cent, and pure nitrogen, which is destined to become of great industrial importance, is obtained as a by-product.

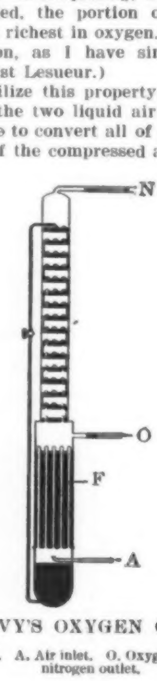


Fig. 3.—LEVY'S OXYGEN GENERATOR.

F. Condensing pipes. A. Air inlet. O. Oxygen outlet. N. (Impure) nitrogen outlet.

But these processes based on the progressive evaporation of liquid air and the simultaneous liquefaction of air under a pressure of three atmospheres yield more or less highly oxygenated air, rather than pure oxygen. The latter may be obtained by a supplementary process precisely similar to the rectification of distilled liquors, which was proposed by Dr. Linde in 1902.

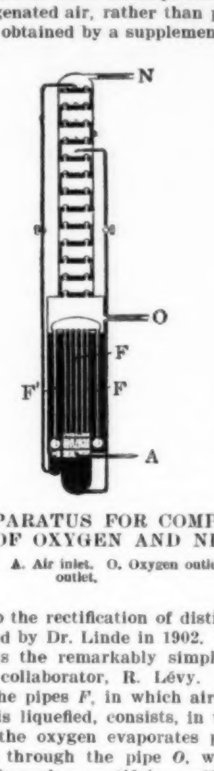


Fig. 4.—APPARATUS FOR COMPLETE SEPARATION OF OXYGEN AND NITROGEN.

F, F'. Condensing pipes. A. Air inlet. O. Oxygen outlet. N. Nitrogen outlet.

Fig. 3 represents the remarkably simple apparatus employed by my collaborator, R. Lévy. The liquid which surrounds the pipes *F*, in which air at three or four atmospheres is liquefied, consists, in this case, of pure oxygen. As the oxygen evaporates part of it is drawn off for use through the pipe *O*, while the remainder ascends through a rectifying cylinder of the usual type. The liquid air (containing 21 per cent of oxygen) which is formed in the pipes *F* flows, through the small pipe on the left, to the top of the cylinder whence it trickles down, from plate to plate, through the ascending column of gas. By reason of its low temperature (—193 deg. C. or —315 deg. F.) it energetically condenses the ascending oxygen, the liquefying point of which is —180.5 deg. C. (—293 deg. F.), releasing a corresponding quantity of the more volatile nitrogen. Thus the liquid becomes continually richer in oxygen as it descends. It is very nearly pure oxygen when it reaches the bottom of the cylinder and joins the liquid oxygen already surrounding the pipes *F*. In this way about two-thirds of the oxygen of the air treated are obtained in the form of pure oxygen, the gas which escapes at *N* containing only 7 per cent of oxygen.

I have prevented this loss and separated the air entirely into pure oxygen and pure nitrogen very simply by combining the return pipe with the principle of rectification (Fig. 4). The compressed air, entering at *A*, rises through the inner pipes *F*, where it is *partially* liquefied, yielding a liquid containing 48 per cent of oxygen, and a gaseous residue of practically pure nitrogen, which becomes liquefied during its passage downward through the outer ring of pipes *F'*, both sets of pipes being surrounded by liquid oxygen. The highly oxygenated liquid air formed in the inner pipes *F* rises, in virtue of its pressure, through the small pipe on the right to the middle part of the rectifying cylinder, while the liquid nitrogen condensed in the outer

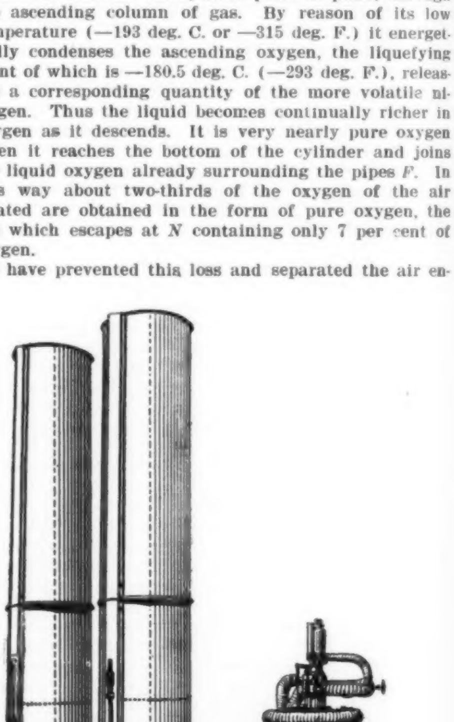


Fig. 5.—GENERATOR 13 FEET HIGH WHICH PRODUCES 36,000 FEET OF OXYGEN PER DAY.

* From La Science au XXme Siècle.

† See L'Air Liquide, by Georges Claude, published by Dunod & Pinot, Paris.

* Comptes Rendus, September, 1900; June, 1902; November, 1905.

† For details see Bulletin de la Société des Ingénieurs Civils, January, 1906.

pipes F' flows, through the small pipe on the left, to the top of the cylinder.

The operation is as follows: In the lower part of the cylinder the highly oxygenated liquid which flows downward from the small pipe on the right gives up all of its nitrogen to the ascending gas, absorbs from this a corresponding quantity of oxygen, and reaches the bottom of the cylinder as practically pure liquid oxygen. In this process the ascending gas is converted from pure oxygen into a mixture of the constitution of common air, containing 21 per cent of oxygen. As this air continues to ascend through the liquid nitrogen dripping from above it gives up all of its oxygen to the latter and arrives at the top of cylinder as nitrogen. In short, the compressed air which enters the apparatus at the bottom, *A*, is separated into practically pure nitrogen which escapes at *N* at the top, and equally pure oxygen which flows out at *O*, at the bottom of the rectifying cylinder.

Two generators constructed on these principles are used by the Liquid Air Company, of Boulogne-sur-Seine. One produces daily 700 cubic meters (25,000 cubic feet), the other 1,000 cubic meters (36,000 cubic feet) of oxygen containing from 2 to 4 per cent of impurities. Fig. 5 gives a general view of the larger generator. At the right is an apparatus for producing liquid air to charge the generator and to supply loss, in the middle of a tower containing the regenerator (the horizontal pipes of Fig. 2), and at the left a similar tower containing the separating and rectifying apparatus just described, and shown in Fig. 4.

The towers are only 13 feet high, yet the output far exceeds the aggregate production of all other oxygen generators in France. The ultimate aim of the new process is the production of one cubic meter (36 cubic feet), or more, of oxygen per horse-power hour—an efficiency twenty or thirty times as great as that of the usual process based on electrolysis of water.

[Continued from SUPPLEMENT No. 1587, page 25436.]

RESERVOIR, FOUNTAIN, AND STYLOGRAPHIC PENS.—IX.*

By JAMES P. MAGINNIS, A.M.Inst.C.E., M.Inst.Mech.E.

FOUNTAIN PENS.

THE "Autofiller," shown in Fig. 206, is, as its name implies, a self-filling pen, whose ink container, like that of the "Automatic," consists of a soft rubber tube, *I*, the rear end of which is closed by a plug, prolonged in spindle form, which spindle, *S*, projects through the end of the barrel, *B*, when the small cap, *C*, is removed. The other end of the container, *I*, clasps the "feed," *F*. The spindle, *S*, may be revolved by the finger and thumb, and the act of doing so causes the rubber container to twist, as the lower end is held fast, thus driving the air out of the container. Placing the point in the ink, and allowing the container to straighten out slowly from its twisted form, the ink quickly rises and fills the container. The disadvantage of these pens lies in the flexible container, which quickly perishes, but a new tube may be had at a very trifling cost, and may be readily substituted for the old one, when the pen will have a new lease of life. The "Autofiller" is very similar to the Conklin pen, the chief difference being the method of manipulating the flexible ink reservoir, by twisting instead of by pressure.

The "Post" pen, illustrated in Fig. 207, and already described, is a pen constructed on the syringe principle. A piston, *P*, fits the barrel, *B*, and is operated by the piston rod, *R*. The idea is to fill the pen by means of the piston arrangement, just as a syringe may be filled. There is nothing special about the feed arrangement, but an ingenious method is adopted of elongating the piston rod. This rod is hollow, and an extension rod, *E*, is provided, which, when not required for use, slides into the hollow rod, lying snugly out of the way. It may be withdrawn a short distance, and then a couple of turns screws it into the rod, *R*, thus making it a more convenient length to use. Before replacing the cap which covers the piston rod, when the pen is in use, the rod, *E*, is unscrewed and slid back into *R*, thus maintaining the length of the pen as normal. A small cap is provided to protect the nib when out of use. The "Post" pen is very well made; it is an excellent form of self-filling pen, but the ink-holding capacity is small. It may be of interest to state that the Salvation Army is responsible for its introduction into this country.

Fig. 208 shows a section of the fountain pen of the Eagle Pencil Company, a firm well known for its ingenious automatic pencil holders. It will be seen that the barrel and point section are in one piece, and that a second barrel, screwed into the first at its upper end, reaches downward to the feed bar. This inner barrel may be entirely removed and filled with ink in the manner generally adopted, and then returned to the position shown in its outer case, thus keeping joints free from ink. The feed bar has a hole drilled right through its center line from end to end, and a branch leading downward for the admission of air, while ink passes along the groove on its upper side to the underside of the nib, which is not shown in the drawing.

In Figs. 209 and 210 appear two excellent sectional views of the "Conklin" pen. The upper one shows clearly the flexible rubber reservoir fully distended, and ready for use. A metal band passes nearly round the casing and through the opening formed in the thumb-piece of the presser bar. In the position shown in the upper view, the presser bar is inoperative, but when the gap in the metal band is brought into the position shown in the lower view, the reservoir may be compressed for filling.

* Journal of the Society of Arts.

Fig. 211 (H. Siegert, 1892, 4739) shows a fountain pen in which the penholder, *C*, is connected by a flexible rubber tube, *B*, to an ink bottle, *E*, the tube passing through a cork or stopper fixed in the bottle, and reaching down to the bottom. A second tube with a rubber ball, *D*, also passes through the stopper, but

In this drawing, Fig. 212 (R. Galland-Mason, 1900, 6279), the ink vessel, *A*, is connected to a fountain pen by means of a rubber capillary tube, *C*. The ink flow is regulated by a spring clip, *B*, which may be placed in any convenient position. The idea is very similar to the previous one, but differs in this respect: In the

Fig. 206.

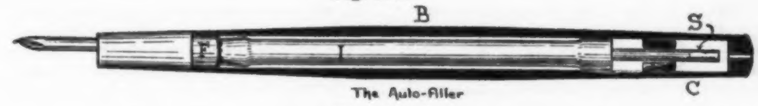


Fig. 207.

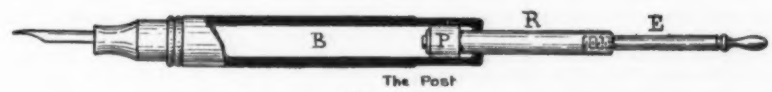


Fig. 208.

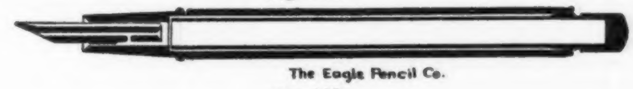


Fig. 209.

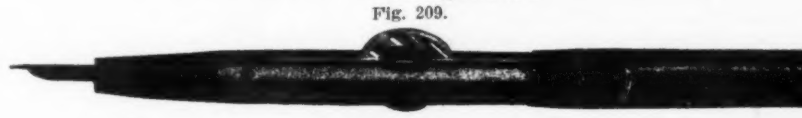


Fig. 210.

Fig. 211.

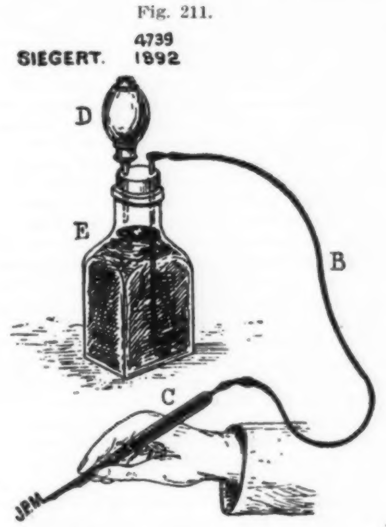


Fig. 212.

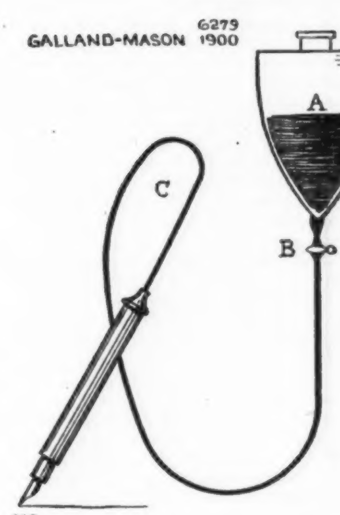


Fig. 213.

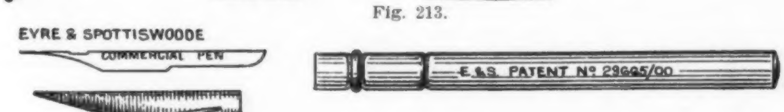


Fig. 214.

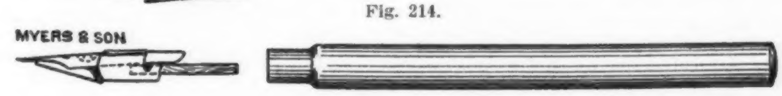


Fig. 215.

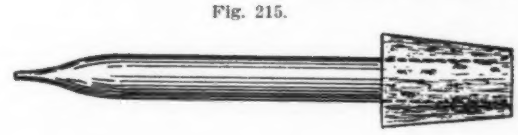


Fig. 218.

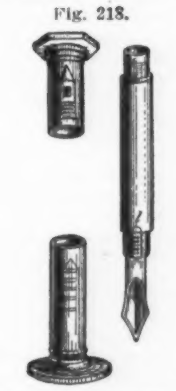


Fig. 216.

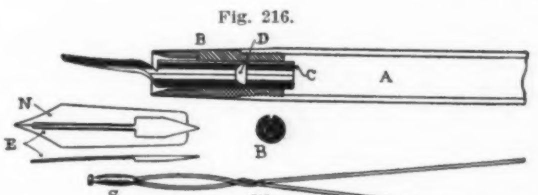
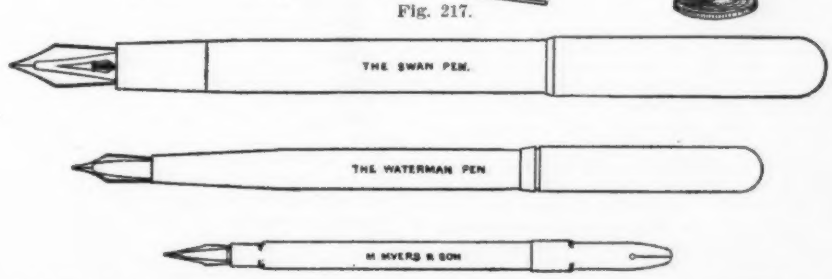


Fig. 217.



does not reach so far downward as to touch the ink. By squeezing the ball, *D*, the pressure of air is increased and ink is forced into the penholder, *C*. The inventor suggests that several pens may be connected to the same ink bottle, each having its flexible connection.

former case the ink arrives at its destination by a syphonic action, stimulated by the action of the rubber ball, whereas in the latter the ink flows by gravity.

Fig. 213 represents a neat little pen sold by Messrs. Eyre & Spottiswoode at the modest price of threepence. The ink-reservoir is made of brass, as many Birming-

ham productions are, and it is intended to be used in combination with any ordinary steel nib which may fit. The nib is held in position by the plug of vulcanite shown underneath it, the cut in which gives it a springlike grip. In this respect it is similar to the "Fleet" or "Fenchurch" pen. Ink is fed to the nib by the saw-cut extending along the upper length of the plug, and which, when in position, lies immediately under the nib. The stricture shown in the barrel prevents the plug from being thrust too far inward.

Messrs. Myers & Son have no intention of being outdone in the matter of price, for in Fig. 214 we have a fountain pen retailed at the very moderate price of one penny. He would indeed be a careful man who expected a fountain pen for less. Like the pen just described, the ink reservoir is of brass. The nib, however, is specially made for the pen, and has a grooved air channel extending along from the butt to about half the length of the nib. The nib is held in a metal penholder continued underneath the point of the nib as shown in the drawing, and capable of holding a considerable quantity of ink. A slip of wood is inserted in the rear of the penholder, to form an ink feeder.

Messrs. Myers have sent me some of these pens, and I am pleased to find that they are really workable. Truly, no one need be without a fountain pen.

I feel that I have nothing to teach those who have been, and are still, designing fountain pens, but perhaps the general public will allow me to tell them how I keep my fountain pens clean. It is, as I dare say many know to their cost, a great mistake for those inexperienced in such matters, to attempt to take all the parts of a fountain pen out of their proper places, owing to the difficulty experienced in putting the various parts back in their correct relative positions. It is also a difficult matter to thoroughly cleanse the minute passages, and free them from foreign matter which will get there, and which becomes hardened and obstructs the flow of ink and air.

The simple device I have shown in Fig. 215 is most effective in its action. It consists of one of the little pipette tubes supplied with fountain pens, fitted into a cork slightly tapered, as you can see. This I place in the water supply tap, with the result that a fine jet of water is produced, issuing from the point at a considerable pressure, so strong that if the point section of the pen be unscrewed and the jet allowed to play into the passages, all impurities will quickly disappear, and the pen be thoroughly cleansed. This is not patented, but it works just as well as if it were, and I advise fountain pen users to try it.

I now want to show you the internal arrangements of the latest "Swan" pen. Fig. 216 shows the ink reservoir, *A*, into which is screwed the point section, *B*. A vulcanite plug, *C*, fits loosely into the point section, and extends in the form of a tapering finger, underneath the nib, reaching nearly to its point. This plug is pierced along its axis by a rectangular hole, and an enlarged chamber is formed at *D*. A narrow tongue of metal, *E*, shaped somewhat like a nib at its rear end, lies along the back of the writing nib, *N*. The double wire, *W*, has at one end a tiny tapering plug or stopper, *S*. When the parts are fitted together, this wire passes through the rectangular hole in the plug, *C*, and the little stopper, *S*, occupies a position in the forward end as shown in cross section at *B*, a round stick in a square hole, thus leaving the four corners open for the admission of air. To fill the reservoir, it is only necessary to slightly withdraw the stopper, *S*, and the air readily finds its way out, through the square hole referred to, while the ink presses inward.

Mr. Watts kindly sent me two of these pens for experimental purposes, one of these being of ordinary proportions, and the other of noble dimensions. I am much pleased with them, especially the latter, and to give some idea of its capacity for ink as compared with other well-known pens, I have here in Fig. 217 shown it alongside the "Waterman" pen, a pen of which I cannot speak too highly, while below it will be seen the penny pen of Messrs. Myers. Shall I call them "Dignity and Impudence," or "The Sublime and the Ridiculous"?

One word as to the cap. There appears to be a tendency to provide a cap which perhaps, to many, is clumsy. Its appearance is evident in the drawings of the "Waterman" and the "Swan" pens. To those who want to know why it is being adopted, I would point out that it is designed as a safeguard against any possible leakage at the joint between the ink reservoir and the point section, which it completely covers, and it fulfills its mission admirably. It might, however, in my humble opinion be improved in design.

Finally, I would repeat that it has not been my intention to make invidious distinctions with regard to any particular make of pen; on the contrary I have endeavored to describe one and all impartially. Where I have had opportunities of testing any of the pens I have spoken of them as I found them, and when I have had any praise to bestow it has been given because I considered such was due. It must not be understood, however, that many other pens may not have equally good features.

It may possibly have been a shock to some to find that the modern fountain pen is the outcome of ideas so old, but after all has been said and done, the most ingenious, or the simplest, or the most scientifically designed fountain pen is bound to be a failure unless it be properly made and properly adjusted. Be the invention old, or be it new, it cannot help but fail in its object, if the skillful hand and intelligent mind of the artisan are not brought to bear on its production.

Perhaps a fitting termination to this lecture would be a description of a fountain pen which my friend, Mr. Bennett H. Brough, has brought to light in a volume published in 1723, being an English translation of Monsieur M. Bion's work on Mathematical Instruments, written and published in French some years previously, in which the instrument was called "plume sans fin," a pen without end. It is, however, in the English translation called a fountain pen. Here is a copy of the drawing (Fig. 218) of the fountain pen which appears in the book, and it will be noticed that the nib employed looks very like a quill. The descriptive matter is very quaint, and I reproduce it here.

Extract from Edmund Stone's translation, 1723, of M. Bion's work on Mathematical Instruments:

"Of the Fountain Pen.—This instrument is composed of different pieces of brass, silver, etc.; and when the pieces, *F*, *G*, *H*, are put together, they are about five inches long and its diameter is about three lines. The middle piece, *F*, carries the pen, which ought to be well slit, and cut, and screwed into the inside of a little pipe, which is soldered to another pipe of the same bigness, as the lid, *G*; in which lid is soldered a male screw, for screwing on the cover; as likewise for stopping a little hole at the place *I*, and so hindering the ink from running through it. At the other end of the piece, *F*, there is a little pipe, on the outside of which the top-cover, *H*, may be screwed on. In this top-cover there goes a porte-craion, that is to screw into the last-mentioned little pipe, and so stop the end of the pipe at which the ink is poured in, by means of a funnel. When the aforementioned pen is to be used, the cover, *G*, must be taken off, and the pen a little shaken, in order to make the ink run freely. Note.—If the porte-craion does not stop the mouth of the piece, *F*, the air, by its pressure, will cause the ink to run out at once. Note, also, that some of these pens have seals soldered at their ends."

HOW TO COOK CEREALS.*

For the average person the proper cooking of cereals is quite as important as the proportions of different nutrients which they contain. Variations in the composition of similar brands are for the most part comparatively unimportant, but it seems fair to assume that indifferent cooking affects more or less the ease of digestion and the amount of nutrients which the body can extract from a dish of cereal and at the same time detracts from the pleasure of eating. The chief purposes of cooking are (1) to sterilize the material, so that any undesirable bacteria or parasites or their eggs if accidentally present may be rendered harmless; (2) to improve flavor and appearance; and (3) to produce such changes in structure that the digestive juices may act more readily upon the nutrients present. Heat, especially that employed in the process of manufacture, improves the keeping quality, though this is not so important in the case of cereal foods as of some other food materials, because if the grains are well cleaned and are marketed and stored under proper conditions they should be free from dirt, mold spores, insects, etc., and, furthermore, they are so dry that they do not furnish a good medium for the growth of molds, bacteria, and other low forms of vegetable life. It is interesting to note that parching as a means of improving keeping quality was practised long before the reasons for the process were known. Thus, the American Indians often parched their corn before storing it, and indeed this practice seems to have been very generally followed since early times in most countries when it was desired to store grains or seeds or to protect them during transportation.

The second purpose of cooking, to improve flavor and appearance, has a value beyond a mere catering to the eye and to the palate, since there may be a direct gain in digestibility. Appetizing foods in some way stimulate the flow of the digestive juices, while those that are eaten without relish seem to retard it.

The third purpose of cooking, to convert the nutrients into more digestible forms, is especially important in vegetable foods which, like the cereals, contain a large proportion of crude fiber. As has been stated, the nutrients of the grain are found inside the starch-bearing and other cells, and the walls of these cells are made of crude fiber, on which the digestive juices have little effect. Unless the cell walls are broken down, the nutrients cannot come under the influence of the digestive juices until the digestive organs have expended material and energy in trying to get at them. Crushing the grain in mills and making it still finer by thorough mastication breaks many of the cell walls, and the action of the saliva and other digestive juices also disintegrates them more or less, but the heat of cooking accomplishes the object much more thoroughly. The invisible moisture in the cells expands under the action of heat, and the cell walls burst; and the water added in cooking also plays an important part in softening and rupturing them. Then, too, the cellulose itself may be changed by heat to more soluble forms. Heat also makes the starch in the cells at least partially soluble, especially when water is present. The solubility of the protein is probably as a rule somewhat lessened by cooking, especially at higher temperatures. Long, slow cooking is therefore better, as it breaks down the crude fiber and changes the starch to soluble forms without materially decreasing the solubility of the protein.

Investigators differ as to the amount of soluble carbohydrates produced by long-continued cooking. Gudeman† reports 38 per cent soluble carbohydrates in cooked as compared with 5 per cent in raw breakfast cereals.

In experiments made with rolled oats at the Minnesota Experiment Station* it appeared that cooking (four hours) did not make the starch much more soluble. However, it so changed the physical structure of the grains that a given amount of digestive ferment could render much more of it soluble in a given time than when it was cooked for only half an hour.

On the basis of the results obtained, the difficulty commonly experienced in digesting imperfectly cooked oatmeal was attributed in a discussion of these experiments to the large amounts of glutinous material which surround the starch grains and prevent their disintegration. When thoroughly cooked the protecting action of the mucilaginous proteid material is overcome, and the compound starch granules are sufficiently disintegrated to allow the digestive juices to act. In other words, the increased digestibility of the thoroughly cooked cereal is supposed to be largely due to a physical change in the carbohydrates, which renders them more susceptible to the action of digestive juices. The rupturing of hard cell walls by the heat of cooking is also of importance, as was pointed out above.

Cereals differ considerably in the amount of cooking required to make them as digestible as possible, but not enough is definitely known on the subject to say exactly how long each kind should be cooked. In general, it is true that the more abundant and coarse the crude fiber the longer should be the cooking period. For this reason whole grains require longer cooking than partially crushed ones, and those containing the skin of the seed more than those from which it has been removed. For instance, whole corn kernels require longer cooking than fine hominy, and whole wheat preparations more than flour gruel. Rice, which is remarkably free from crude fiber, can be thoroughly cooked in a comparatively short time.

In the case of the partially cooked cereals it is difficult to know how much of the necessary cooking has been done at the factory. It is safe to assume that they still require at least all the cooking suggested in the directions usually accompanying the package and probably would not be harmed by considerably more. Physicians sometimes complain that these preparations are indigestible and prefer old-fashioned home-cooked grains. Yet it is hard to see why the partially cooked cereals, if they are properly recooked before serving, should not be just as digestible as those cooked entirely at home, and they certainly permit some economy in fuel and time. With all cereals it should be remembered that overcooking is unusual and harmless, while undercooking is common and undesirable.

Recent experiments on the digestibility of the protein of oatmeal indicate that this nutrient is more thoroughly digested when the meal is well cooked than when only slightly cooked, and also when the oats are rolled or malted than when simply crushed and boiled, probably because the increased heat or pressure or the action of the malt breaks down more of the cell walls. In other experiments, where the digestion of the protein of the wheat was artificially imitated by the use of pepsin, raw separated gluten was found more digestible than cooked, and gluten gruel more digestible than gluten wafers. Such experiments, however, represent only a part of natural digestion, and their results would be of importance mainly in the case of invalids, as the whole process of digestion of normal persons would probably insure reasonably complete digestion.

When cereals are cooked in water two kinds of changes occur besides those already referred to—i. e., part of the water is absorbed into the grain and part of the solid matter passes into the water. Some cereals absorb much more water than others before they are sufficiently cooked to be at their best. This probably depends largely on the amount of time required for cooking. Raw oatmeal contains only 7 per cent of water, but when cooked 84 per cent, according to recent analyses. On an average the amount of water in hominy increases from 11 to 79 per cent in cooking and that in rice from 12 to 72 per cent. If we consider cereals in the form in which they come on the table, we certainly get a larger proportion of nutrients from those that absorb the least water. Because it is drier a saucer of cooked rice actually has a higher food value than a like quantity of cooked oatmeal. From this it might be argued that the dry ready-to-eat cereals are preferable to those cooked at home, but this is not necessarily the case. Many persons, if they do not actually soften the dry and ready-to-eat cereal foods with hot water before serving, add considerable milk or cream to them and so make a saucerful about equal in moisture content and total food value to a like dish of any other cereal.

There are probably differences in the amount of solid matter removed by water in cooking different cereals, but little is definitely known on this subject. If rice is boiled in an abundance of water, the latter becomes thickened and forms a sort of starch paste, showing that some material may be lost in boiling rice if the water is thrown away. This is one of the reasons why many persons prefer steaming to boiling as a method of cooking this food. In most cases the losses in cooking cereal foods are probably negligible. When milk, sugar, salt, etc., are added to cereal foods in cooking or serving, the total food value of the dish is, of course, greater than that of the cereal alone.

Some instances of the practical application of the fact that part of the nutrients of cereals are soluble in water may not be without interest. Barley water, an old-fashioned beverage much thought of in the sick

* Abstracted from Farmers' Bulletin 249, issued by the Department of Agriculture.

† Journal American Chemical Society, vol. xxvi. (1904), p. 321.

* Minnesota Sta. Bul. vol. lxxiv., p. 158.

room, is made by boiling barley in water and straining the clear liquid from the undissolved barley. Oatmeal water is a similar preparation often given to sick persons. It is also frequently used as a beverage by athletes and by workmen engaged in severe labor, as it is believed to quench thirst more satisfactorily than water. This beverage is prepared by mixing the raw oatmeal with water, stirring it thoroughly and allowing the coarser particles to settle. Some material is dissolved and some fine particles undoubtedly remain suspended in the liquid, which takes on a somewhat milky appearance.

Gruels—that is, thin porridges made from oatmeal, rice, corn meal, etc.—are usually cooked for a long time and owe their characteristic consistency largely to starch in the form of paste, i. e., hydrated and gelatinized starch, though undoubtedly some insoluble material is retained in suspension. By passing the material through a sieve the coarser undissolved portions of the grain are removed and a smooth, more or less thick mass remains, which contains a considerable amount of nutritive material. When well made and seasoned such porridges or gruels are very palatable. At the same time the dish is so dilute that it does not overtax weakened digestive organs.

Of course, the amount of nutritive material in gruel depends largely on the proportions of water and cereal used. In recent analyses it was found that strained gruels made with a quart of water and an ounce of barley, rolled oats, or wheat flour contained on an average about 2 per cent of solid material, while 8 ounces of cereal with the same quantity of water gave 18 to 20 per cent of solids. Dextrinized oats and wheat yielded a richer gruel than the ordinary grains.

CONTEMPORARY ELECTRICAL SCIENCE.*

ELECTROSTRICTION.—The theories of Faraday and Maxwell assume a tension along the lines of force in a dielectric and a pressure at right angles to them. Attempts have been made at various times to prove the existence of such stresses in a material dielectric, but none are free from objections. The modern tendency is to regard these stresses as purely fictitious, and as alternative expressions for the energy stored in the medium. The immobile ether assumed by Lorentz precludes the existence of electrostriction in the ether itself, and any deformation of a dielectric would have to be due to the displacement of electrons immersed in it under the influence of electrostatic force. But that such displacements should give rise to the Faraday-Maxwell electrostriction is very improbable. L. T. More has attempted to decide the question experimentally. He constructed a pillar consisting of alternate disks of brass and dielectric. The latter was a mixture of four parts by weight of the best shellac, one of resin, and two of Venice turpentine. This compound gives a clean and smooth surface when broken, and is highly elastic. The brass plates were 5 centimeters in diameter, 2.5 millimeters thick, and 31 in number. The odd brass plates were charged positively and the even ones negatively. Thus the top and bottom plate were similarly charged, and they were connected by stout brass rods. An optical lever was used to determine any change of length of the pillar when charged, but no such change was discovered, even with potentials close to the limit of the insulating power of the dielectric. The author, therefore, concludes that dielectrics are not distorted by electric forces, and that all apparently positive results are due to extraneous causes.—L. T. More, Philosophical Magazine, December, 1905.

DISCHARGE THROUGH GASES.—J. Stark reviews the present condition of research on gas discharges. These discharges he distinguishes as dependent and independent currents, meaning that in the first class the necessary ionization depends upon the presence of an ionizer like X-rays or some other agent, whereas in the second class the discharge produces its own ions independently by collision. The first class is the better known of the two, and has been pretty fully worked out since Thomson and Townsend determined the coefficients of ionization and recombination and the transport and absorption of ions. The independent discharges comprise the positive point discharge, the glow discharge, and the electric arc. In spite of a great accumulation of material, no mathematical theory of these discharges has yet been formulated. The author expects that much light will be thrown upon it by an investigation of spectra in vacuum tubes. A gas does not show its line spectrum unless it is both hot and ionized. The source of the line spectrum is evidently the kinetic energy of the ions. The source of the band spectrum is, on the other hand, the potential energy of ions of opposite signs, liberated during recombination. The constitution of the atom may be elucidated along this line of research.—J. Stark, Physikalische Zeitschrift, November 9, 1905.

PROJECTION OF CATHODE PARTICLES.—The manner in which electrons are projected from the cathode is open to some doubt on account of a discrepancy in the value of the ratio e/m obtained by two different methods. The method of electrostatic deviation used by Thomson gives 0.8×10^7, while the calculation of the potential made by Kaufmann and Simon gives double that value. In the latter case the difference of potential fallen through by the electron is assumed to be that between the cathode and the observation space. This again assumes that the electron is liberated at the cathode itself, which remains to be proved. J. Malassez has essayed such a proof by a method devised by Langevin. It consists in directly determining the difference of potential under which the rays are produced by observing the change of velocity imparted to them by a second magnetic field. If, after traversing a difference of potential V and thus acquiring a velocity v_1 the cathode rays are made to work up against another difference of potential, V', the resultant velocity v_1 will be determined by the equation $\frac{1}{2}mv_1^2 = (V - V')e$. Now let the rays be deflected by a magnetic field, and acquire a radius of curvature ρ. With only one difference of potential to traverse we have $Hev = mv^2/\rho$. With the additional V', let the magnetic field be so arranged that the curvature is the same as before. Then we have $mv_1^2/\rho = H_1ev_1$ and $V'/V = (H^2 - H_1^2)/H^2 = (i^2 - i_1^2)/i^2$, where ii_1 are the magnetizing currents. The ratio on the right hand side is easily determined, and since V' can be accurately fixed, V is known. If it is equal to the difference of potential between anode and cathode, it proves, then, the rays or electrons are projected from the cathode itself. The author finds that that is the case, and that the great velocity is acquired from the cathode itself.—J. Malassez, Comptes Rendus, November 27, 1905.

* Compiled by E. E. Fournier d'Albe in the Electrician.

SCIENCE NOTES.

Czapek found no enzymes to occur in the excretions from the roots of higher plants, and it is now generally believed that the roots of one plant may develop no excretions injurious to neighboring plants, and, therefore, there may be no biological relation between the roots of non-parasitic plants associated in the given plant society. It must be said, however, that the information at hand may not be taken as final. There are yet some peculiar facts with relation to the rotation of crops which may not be readily explained on the grounds of the exhaustion of plant nutrients or of the physical condition of the soil. The fermentation of tobacco and tea, or hay and manure, involves enzyme actions which in recent times have received some attention, although the problems which are of most physiological importance require solution. The general belief is that in all cases of enzyme action these compounds do not form a part of the substance upon which their action is exerted, but they act as a key in each particular case, unlocking, or rendering labile, a certain organic compound, which is then subject to rearrangement and transformation. This is all, however, too speculative for profitable consideration, although such speculation may have no evil influence if it is not permitted to encourage the reference of all unusual phenomena to an unusually obscure and difficult process.

The step really leading to a clear and unobjectionable notion of chemical affinity was made in the study of the so-called reversible chemical changes. This reversible character perhaps needs some explanation, easily to be provided by an illustration. Kill a chicken and prepare chicken soup; it would then be very difficult to get your chicken again. This is because preparing chicken soup is not reversible. On the contrary, let water evaporate or freeze; it will be easy to reproduce the water. Now, at first sight, chemical change does not seem reversible; and indeed it often is not, as in the explosion of gunpowder. But investigations of Berthelot and Péan de St. Gilles on the mutual action of acids and alcohols, and those of Deville and Debray on high temperature action, which even splits up water, have shown that many chemical changes can be reversed. Indeed, we have types corresponding absolutely to evaporation, as the loss of water vapor from hydrates; and others corresponding as well to freezing and melting, as the splitting of double salts into their components at definite temperatures, e. g., copper calcium acetate at 77 deg. C. Also in analogy with physical phenomena, we have in these reversible chemical changes the possibility of equilibrium, the two chemically different forms of matter coexisting, as do water and its vapor at a maximum pressure.

Regarding the question of earthquakes, M. Camille Flammarion, the eminent French scientist, stated in a recent interview that we are unable to affirm in the present state of science, that sunspots have the influence which is commonly supposed upon seismic effects. Some savants think that earthquakes almost always coincide with the maximum intensity of the sunspots. However, the Martinique catastrophe took place just when the spots were at their minimum. It is very difficult, I repeat, to find the circumstances which cause the subterranean revolutions. Thus the earthquake in Spain was preceded by atmospheric disturbances such that engineers could not use the barometer for finding the altitudes as usual. On the other hand, at the time of the Nice earthquake the circumstances were quite different. The atmosphere was absolutely calm, and the pressure reached 770 millimeters. However, the statistics furnished by the scientist Perrey show that there is a somewhat greater number of earthquakes at the new and full moons than at the quadratures, and that the attraction of the sun and moon seem to act as they do for the tides, but with much less force, also that a few hours before the Nice earthquake of the night of February 27 there was not only the new moon, but also a central eclipse of the sun, as the earth, moon and sun were on the same straight line. Is this coincidence only accidental? It would be rash to affirm it. The day may come when science, which has already discovered the causes of these cataclysms which put the whole of humanity in mourning, will be able to forewarn us of these convulsions of the soil in time to allow us to avoid these sad and irreparable events. Up to the present, all that has been written about these previsions, especially as regards the phases of the moon, seems to me very doubtful. For instance, as I just mentioned, the Martinique catastrophe coincided with the new moon, and the year 1902 is an epoch where our satellite was well approached toward the equator. The sun and moon were even above the latitude of Martinique at the time of the catastrophe, and there was an eclipse of the sun upon that day. But the eruption of Krakatoa, which was much more powerful, took place at the last quarter of the moon. The eruption of May 20, which was very violent, took place two days before full moon. Thus we find that the moon's phases, etc., do not correspond satisfactorily so as to give us any definite conclusion, but it is to be hoped that further progress of science will throw some light upon the question.

The metal terbium has been the object of a series of researches which G. Urbain carried on at Paris. He is able to obtain the metal in a pure state. He also showed that we must attribute to this metal different spectral characteristics which have been hitherto considered as belonging to other elements as yet not fully known. These characteristics have only been observed up to the present in ythia-bearing earths which are not fully purified. The method which he employs for determining the atomic weight of terbium consists in finding the weight of water in the octohydrated sulphate $(SO_4)_3\ Tb_2,\ 8H_2O$. The sulphate was prepared by precipitating the sulphuric acid solution by a great excess of alcohol. The precipitates are washed with alcohol. After drying at 110 deg. C., the sulphates are dissolved in water and the solution, which is quite neutral, is concentrated on the water-bath. The crystals which are thus obtained consist of the octohydrate of terbium. This salt is not changed in dry air at the usual temperature. De-hydration of the salt was carried out by slowly raising the temperature. To eliminate the last traces of water, it is necessary to heat it finally to near 360 degrees. Weighing the anhydrous sulphate shows a slight uncertainty owing to the fact that it absorbs gases from the dry air, but it absorbs them more slowly and to a less degree than sulphate of gadolinum, so that this error can be almost eliminated by weighing rapidly as soon as the crucible is cooled off. Thus operating, M. Urbain secured a series of very concordant numbers. The mean value of the atomic weight he finds to be 159.22. As to the spectrum of terbium, he expects to give some interesting points in a future paper. The spark spectrum is very rich in rays. Of these he gives a list of the most characteristic rays. Some of these Demarçay attributes to an element which he calls Γ. We note a few of the strongest rays of terbium as follows: 3053.6, 3079.0, 3220.5, 3324.5, 3509.5, 3561.8, 3703.0, 3848.8.

ELECTRICAL NOTES.

The driving of alternating-current dynamos is an altogether different problem from that of the direct-current machine, excepting when they are not to be driven in parallel, in which case the conditions are the same as with continuous-current dynamos. When, however, they have to be driven in parallel very much greater steadiness is required. The writer has had to do with several installations in which alternators have been driven in parallel by means of single-cylinder Otto type engines. In these cases, however, they have been fly-wheeled to at least double the extent of the particulars given of the previously mentioned engines, and our old friend the long-belt drive has been used, the engines themselves being fitted with a very sensitive arrangement of automatic regulation which always proportioned the impulses to the load. It is of interest to know that without this automatic regulation the alternators would not run in parallel, but with it in action they have been satisfactory.

Since storage cells were first introduced, the demands upon their electrical capabilities have steadily increased. The early storage cells of Planté were electrolytically formed from plain parallel leaden sheets in the course of weeks and months of preliminary charging and discharging, before they were regarded as fit for duty. When on duty they were not allowed to discharge to the practical low-voltage limit in less than six hours, and the period of recharging was not less than 24 hours. It would have been regarded as highly insulting to a storage cell of that day, not to say injurious, to ask from it a full charge and discharge in one and the same day. At the present time, however, central station storage batteries are commonly charged in six hours, and discharged in two. Although it is admitted that the efficiency of such a battery would be greater if it had a more leisurely day's work, yet the necessities of central station distribution prohibit the eight-hour-day working rule for storage batteries, and require three-hour working days, two-hour working days and even one-hour working days.—Electrical World and Engineer.

Other conditions being the same, the power taken by a machine tool, after allowance is made for friction losses, will vary approximately as the speed and cut, and therefore as the weight of metal removed, consequently in fitting motors to tools allowance must be made for high speeds and maximum cuts, bearing in mind the coming universal use of high-speed tool-steels and the increase in rigidity of machines. In general, the power required to drive a machine can be computed by multiplying the weight of metal removed per minute, in pounds, by a coefficient depending upon the kind and grade of the material. This coefficient ranges from 1.4 for cast iron, to 3.6 for hard steel, with intermediate values for materials of hardness between these limits. Of course, the condition of the cutting tool has much influence upon the power consumption, and a dull tool, or one of improper form,

may cause a much greater amount of power to be uselessly consumed. The friction losses in machine tools which run continually in the same direction, as lathes, drill presses, etc., are not very great, and, so far as can be ascertained, these losses do not bear any direct proportion either to motor speed or to spindle speed.

ENGINEERING NOTES.

The steam consumption per indicated horse-power in a locomotive necessarily depends upon the conditions of speed and cut-off. For the simple freight locomotives tested the average minimum is 23.7. The consumption when developing maximum power is 23.8, and when under those conditions which proved to be the least efficient, 29.0. The compound locomotives tested, using saturated steam, consumed from 18.6 to 27 pounds of steam per indicated horse-power-hour. Aided by a superheater, the minimum consumption is reduced to 16.6 pounds of superheated steam per hour.

It may be taken as established that an ideal concrete is one in which the interstices of the finer parts of the aggregate were filled with cement, while large voids in the substances were filled with the mortar so formed. Stone or gravel of graded rather than uniform size is probably best for the aggregate; in using broken stone, the usual custom is to have the run of the crusher; in using gravel or broken brick, a variety of sizes is also insisted on. It may be noted that for most sorts of stone it is a waste of time and money to go to the trouble of excluding the crusher dust, unless there is a demand for it as a commodity in itself. As regards the sand, the tendency is to give a preference to the rounded material over the sharp, crushed quartz sand.

A series of efforts to produce calcium-iron alloys by introducing calcium into molten iron and steel in various ways, such as stirring the molten iron with a rod of calcium, throwing pieces of calcium into ladles and molds during casting, and also by heating the two metals in contact *in vacuo*, both in form of filings and as solid rods fitted tightly into holes bored in a cylinder of the other metal, is described by C. Quasebart in an article entitled "Can Calcium be Alloyed with Iron?" published in Metallurgie. In all cases negative results were obtained, samples of the iron on analysis showing no trace of calcium, so that the use of this metal for alloying or de-oxidizing purposes is not possible. The author points out that in the analysis of samples of iron for calcium, special precautions must be observed, since calcium is readily absorbed in small quantities from glass and porcelain.

Blast furnaces are subject to certain unavoidable irregularities on account of which a "coefficient of safety" must be introduced in the calculation for determining the available power from a blast furnace of a given capacity. This coefficient is of course extremely variable and depends largely upon the pig iron market (which might require a banking of the furnaces), upon the operation of the furnaces, and the quality and supply of ore, coke, etc. It is very difficult to foretell how much of the total theoretical available horsepower from the 400-ton furnaces could actually be realized, especially when the electric power generated by using this gas in gas engines is to be sold to outside consumers to whom the delivery of a certain amount of power naturally must be guaranteed, perhaps under a heavy penalty. This irregularity in the operation of a blast furnace will have a very great influence on the production of gas, affecting the quantity as well as the quality. With two blast furnaces only it would be perfectly safe to figure on the available horse-power from the gas of one furnace, assuming this coefficient to be 0.5. Following the above outlined order of ideas a blast furnace plant of only two 400-ton furnaces should be equipped in the beginning with a power station of only limited capacity corresponding to the available power from only one furnace, installing later on additional units, if the conditions and operations of the furnace plant would be such as to safely permit the generation of additional electrical power.

The method of starting gas engines by means of compressed air seems to be the most satisfactory system in vogue. The air supply is obtained from a small compressor and stored in iron tanks. The method of starting the Westinghouse engine by this means is as follows: A screw is provided, which on being given a few turns renders the admission valve of one cylinder inoperative for the time being. On the back of the crank case is a short lever which on being moved to the right throws out the regular exhaust cam and throws in a supplementary cam which keeps the exhaust valve open during every upstroke, instead of *every other* upstroke of the piston as when the engine is in regular operation. A pipe leads from the air storage tank to the starting valve and thence through a check valve into the cylinder, in which the valve functions have been altered. This valve is actuated by a cam on the lower end of the cam shaft, where it projects through the end of the crank case, and is so timed as to open each time the piston starts on its downward stroke. It will be seen that one cylinder is thus converted into a compressed air engine without disturbing the rest of the engine. The engine being set with the corresponding crank a little over the center, the air and gas supply being properly adjusted, and the stop valve in the air pipe opened, it starts off and continues to run on the air pressure until explosions take place in the other cylinder or cylinders. The air supply is then shut off, the inlet and exhaust valves put back in their normal working positions, and the engine is in full operation.

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

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